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SWITCHER LOCOMOTIVE

CONCEPTUAL STUDY

Prepared for

TRANSPORTATION DEVELOPMENT CENTRE

Montréal, Canada

by

BOMBARDIER INC.

July 1984

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre.

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17. Abstract

This report reviews and summarizes the North American locomotive fleet, emphasizing those areas pertinent to switching and branch line operations. A survey concluded that much of the motive power used for switching service consists of downgraded road locomotives that are worn out and no longer efficient to operate.

The survey also identified a need for a general purpose locomotive suitable for a wide range of operations. This requirement is addressed in the locomotive configurations resulting from the conceptual design studies and presented in this report. Improved adhesion and reduced fuel consumption anticipated for this new design should provide life cycle cost incentives to prospective users.

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17. Résumé

Ce rapport présente les résultats d'un sondage concernant le parc de locomotives en Amérique du Nord, notamment les locomotives utilisées pour les manoeuvres dans les gares de triage et les voies de service. D'après le sondage, la plupart de ces engines sont d'anciennes locomotives retirées du service, usées et inefficaces.

Le sondage a également mis en évidence le besoin d'une locomotive de catégorie générale capable de répondre à une vaste gamme d'utilisations. Les études conceptuelles dont il est question dans le rapport proposent un certain nombre de configurations susceptibles de répondre aux exigences définies dans le sondage. Il s'agit d'un engin caractérisé par une meilleure adhérence roue-rail et une consommation améliorée, et dont le coût global sur la durée de vie est de nature à intéresser les utilisateurs éventuels.

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Locomotive de manoeuvre, engin, moteur, refroidissement, traction	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires

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SUMMARY

A market survey was conducted to assist in identifying user requirements in the lower power range of locomotive applications. This was accomplished with the use of mailed questionnaires which in several instances were followed by personal visits to various railroad operating departments. The results of the survey disclosed an as yet unfilled need, especially on the part of the Class I railroads, for a general purpose locomotive with a spacious, comfortable cab and superior visibility from the driver's position for switching purposes. Although a lesser requirement for a slow speed switching locomotive was identified, Bombardier, for commercial and economic reasons, has elected to address only those requirements that can be met by the existing 6-251 and 8-251 or the new 6-B2400 and 8-B2400 diesel engines currently under final stages of development.

A locomotive specification was developed incorporating those features most frequently mentioned in the survey. This specification was then used as a basic document fundamental to the task of major locomotive component selection, which was conducted first by contact with those suppliers who already had suitable components in their existing product lines. This was followed by development of preliminary specifications for those components which would be required to be new or substantially different from those already available in the market.

A conceptual design for this new locomotive was next prepared using the modular approach to pre-packaging components and/or systems and with special emphasis on standardization and utilization of major wearing components common to other classes of Bombardier locomotives.

Finally, a limited cost analysis was conducted to place a monetary value on the new locomotive on the basis of life cycle cost comparisons with existing motive power and thus to establish the economics for purchasing new units.

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1. INTRODUCTION

North American railroad operations have traditionally employed low-powered switcher-type diesel-electric locomotives for most car movements that are not directly associated with high-speed mainline service. These locomotives are characterized by a single center or end cab sufficiently elevated over the hoods such that an unobstructed view is possible in all directions. The average age of the switcher population is indicated in recent studies to be more than the normal expected life span (20-30 yrs) for railroad motive power. Several factors must be considered in assessing the reasons for this high average age. Among the more significant are:

- Lower duty cycle promoting longer life in switcher service.
- Downgrading of road power to switcher service by the larger railroads.
- Changes in railroads brought about by consolidations and revised methods of operation.
- Rebuilding and modernization of motive power in railroad shops and by contractors.

Many of the older locomotives assigned to limited switching and branch line service will continue to survive in operation as long as repair parts are available. However, the rising cost of fuel has now moved energy to the top of the list of locomotive life cycle cost elements, and, except for modernized rebuilt units, the fuel efficiency of the entire aging switcher fleet is far below standard.

From the foregoing it follows that modern technology, when applied to this lower power class of locomotives, should be capable of producing fuel-efficient designs that will provide a substantial life cycle cost incentive for operators of over-age motive power.

2. MARKET STUDY

2.1 Introductory Remarks

At the time this study was conducted most major railroads in the U.S.A. and Canada had some of their locomotive fleet stored due to the economic downturn. A financial problem also existed since most of the railroads did not have the capability of obtaining funds for new additional motive power. There were some exceptions, of course, since a few railroads were in the process of acquiring new motive power because of obvious life cycle cost incentives. Any new acquisition had to be justified by offering overpowering incentives such as drastic improvements in fuel efficiency, adhesion, and reliability, significantly reduced maintenance requirements, and last but not least: an attractive price. At that time, signs of an economic upturn were essential for any decisions to increase acquisition of new motive power. In fact the U.S. Class I railroads, with several hundred units in storage, continued to phase out, scrap, or sell their non-standard units such as ALCO, Baldwin or those of any other extinct builder. This was part of their ongoing cost reduction and standardization plans because the logistics for maintaining units from builders that are no longer in production often leads to unnecessarily high motive power costs.

Short-haul and industrial railroads, however, have in many cases, bought up old ALCO's from Class I railroads who were retiring them, and used them to replace some of their own aging units, which they could no longer maintain at a reasonable availability rate.

During the course of our visits to several of the larger Class I railroad operating departments we were made aware of a more or less universal desire for an all-purpose locomotive in the 1500-2400 HP range. This hypothetical locomotive would provide room for as many as 5 people in the cab and be capable of operating reliably in often remote locations far removed from established maintenance facilities. It would also be required to be M.U.-compatible for operation, when desired, in high-speed mainline freight consists. Drastically reduced life cycle cost over present day units would be mandatory. It was obvious from discussions with the railways that a new design meeting these criteria would generate a market of its own.

2.2 Market Distribution

The following tables present the distribution of diesel-electric locomotives among the railroads according to builders and country of operation. Table 1 lists the Canadian Class I railways and the number of locomotives on the properties from the various builders.

Table 2 presents data for U.S. Class I operators. Table 3 and Table 4 show data for Canadian and U.S. short-line operators while Table 5 and Table 6 depict the composition of industrial locomotive fleets in Canada and the U.S.A. Table 7 shows the transportation authorities which operate passenger commuter service provided for cities and/or states with government financing. AMTRAK and VIA, however, are classified as Class I Railroads. Table 8 shows the distribution of builders for locomotives operating in Mexico, which is regarded as part of North American domestic operations since their requirements and axle loadings comply with AAR and FRA. Information regarding the classification of each individual Mexican Railroad has not been made available, therefore they are all shown in the Class I tabulation. The above tables include all models of diesel-electric locomotives in all power ranges. The columns marked GM include both EMD and GMD. The total quantity of existing locomotives is not complete since it was not possible to collect all the necessary information from every railroad on the continent within the time span allowed. Table 9 summarizes the above data according to railroad classification and geographical area. Table 10 represents the average age of Bo-Bo locomotives from each builder in each power range. The highlighted area reflects the scope this study is most concerned with, i.e. 746 - 1491 kW (1000 - 2000 HP). Statistical information has been obtained from several different publications to supplement that received from the railroads. The validity of this information is as follows:

- Information concerning USA — Year 1981
- Information concerning Canada — Year 1983-84
- Information concerning Mexico — Year 1981
- Information from the railroads — Year 1982-83.

Unless otherwise noted the following pertains to the above statistical data:

- Diesel-electric locomotives only
- Does not include locomotives built by the railroads.
- Does not include slugs, mates or booster units.

RAILROAD	TOTAL	%	GMC	%	GE	%	BBD	%	OTHERS
British Columbia Railways	126	100	12	9.5	-		114	90.5	-
Canadian National Railways	2054	100	1519	74	3	.1	532	25.9	-
Canadian Pacific Railways	1263	100	936	74	-		327	26	-
Ontario Northland Railways	38	100	33	87	-		5	13	-
VIA Rail Inc.	160	100	87	54	-		73	46	-
TOTAL	3641	100	2587	71.	3	. 1	1051	28.8	-

TABLE 1

CLASS I RAILROADS - CANADA

LOCOMOTIVE FLEETS
AND BUILDERS

	RAILROAD	TOTAL 100%	EMD	%	GE	%	ALCO	%	OTHERS	%
	Amtrak	302	246	81.4%	11	3.6%	45	14.9%	-	
	Atchison, Topeka & Santa Fe	1962	1554	79.2	405	20.6%	3	.2	-	
	Bessemer & Lake Erie RR	76	76	100	-		-		-	
	Boston & Maine	160	158	99	1	.5	1	.5	-	
	Burlington, Northern	3387	2824	83.4	563	16.6	-		-	
(1)	Chessie System	2037	1915	94	122	6	-		-	
	Chicago & North Western	1153	1107	96.0	-		46	4.0	-	
	Chicago, Milwaykee, St. Paul & Pacific RR.	460	456	99.0	4	1.0	-		-	
(2)	Clinchfield RR.	94	94	100	-		-		-	
	Conrail	4197	3503	83.5	651	15.5	43	1	-	
	Delaware & Hudson RY.	137	52	38.0	24	17.5	61	44.5	-	
	Denver & Rio Grande West. R.	24	24	100	-		-		-	
	Duluth, Missabe & Iron Range R.	74	74	100	-		-		-	
	Elgin, Joliet & Eastern Rly.	100	100	100	-		-		-	
	Florida East Coast Ry.	66	66	100	-		-		-	
	Grand Trunk Western RR	266	261	98	-		5	2	-	
	Illinois Central Gulf	1128	1104	97.9	14	1.2	-		10	0.9%
	Kansas City Southern Lines	261	261	100	-		-		-	
(2)	Louisville & Nashville RR	1181	783	66.3%	299	25.3	99	8.4	-	
	Missouri-Kansas-Texas RR	204	187	91.7	3	1.5	6	2.9	8	3.9
	Missouri Pacific RR	1460	1272	87.1	188	12.9	-		-	
	Norfolk & Western RY.	1384	1228	88.7	92	6.6	64	4.7	-	
	Pittsburgh & Lake Erie RR	99	77	77.8	22	22.2	-		-	
(2)	Seaboard Coast Line RR	1295	942	72.7	353	27.3	-		-	
	Soo Line RR	245	233	95	10	4.1	2	.9	-	
(3)	Southern Pacific Trans. Co.	2615	2232	85.4	372	14.2	11	.4	-	
(4)	Southern Ry. System.	1452	1307	90	145	10	-		-	
(5)	Union Pacific RR	1741	1435	81.8	311	17.9	5	.3	-	
	Western Pacific RR.	152	118	77.6	34	22.4	-		-	
	TOTAL	27712	23679	85.4%	3624	13.1%	391	1.4%	18	.1%

(1) Chessie System consists of: Chesapeake & Ohio RY.
Baltimore & Ohio RR.
Western Maryland RY.
Atlanta & West Point.

(2) Part of Family Line System: Others: Georgia RR
Western RY. of Alabama.

(3) Southern Pacific Transp. Co. consists of: St. Louis-Southwestern RY. (Cotton Belt).
Northwestern Pacific.

(4) Southern RY System consists of: Central of Georgia RR.
Alabama Great Southern RR.
Cincinnati, New Orleans & Texas Pacific RY.

TABLE 2

CLASS I RAILROADS - U.S.A.

LOCOMOTIVE FLEETS AND BUILDERS

RAILROAD	TOTAL	%	GMC	%	GE	%	ALCO/MLW/BBD	%	OTHERS
Algoma Central	31	100	31	100	-	-	-	-	-
Duluth, Winnipeg & Pacific	12	100	12	100	-	-	2	-	-
Essex Terminal	2	100	-	-	-	-	-	100	-
Newfoundland Line	51	100	51	100	-	-	-	-	-
Northern Alberta Railway	21	100	21	100		-	-	-	
Quebec North Shore	76	100	76	100	-	-	-	-	-
Quebec Cartier	54	100	7	13	-	-	47	87	-
Toronto, Hamilton & Buffalo Ry	14	100	14	100	-	-	-	-	
White Pass & Yukon	25	100	-	-	13	57	12	48	-
TOTAL	296	100	212	74.1	13	4.6	61	21.3	-

TABLE 3

SHORT-HAUL RAILRAODS - CANADA (CLASS II & III)

LOCOMOTIVE FLEETS
AND BUILDERS

TABLE 4

SHORT-HAUL RAILROADS U.S.A. (CLASS II & III)

LOCOMOTIVE FLEETS

AND BUILDERS

	TOTAL FLEET 100%	EMD	%	GE	%	ALCO	%	OTHERS	%
Alaska RR	63	59	93.7%	4	6.3%	-	-	-	-
Alton & Southern Ry.	21	19	90.6	1	4.7	1	4.7	-	-
Ann Arbor RR	16	10	62.5	-	-	6	37.5	-	-
Ashely Drew & Northern Ry.	9	9	100	-	-	-	-	-	-
Atlanta & St. Andrew Bay Ry.	12	10	83.3	-	-	2	16.7	-	-
Atlanta & West Point RR.	12	12	100	-	-	-	-	-	-
Bangor & Arosstook RR	45	45	100	-	-	-	-	-	-
Belt Railway of Chicago	48	41	85.4	-	-	7	14.6	-	-
Birmingham Southern RR	27	27	100	-	-	-	-	-	-
Cedar Rapids & Iowa	8	8	100	-	-	-	-	-	-
Central Vermont Ry	32	30	93.8	-	-	2	6.2	-	-
Chattahoochee Industr.	8	1	12.5	-	-	7	87.5	-	-
Chicago & Illinois Midland Ry.	20	20	100	-	-	-	-	-	-
Chicago South Shore & S.B.	10	10	100	-	-	-	-	-	-
Colorado & Wyoming Ry.	18	18	100	-	-	-	-	-	-
Detroit, Toledo & Tranton RR	73	73	100	-	-	-	-	-	-
Detroit, Toledo Shore Line	10	10	100	-	-	-	-	-	-
Georgia RR	36	36	100	-	-	-	-	-	-
Green Bay & Western RR	19	-	-	-	-	19	100*	-	-
Green Mountain Railroad	5	-	-	-	-	5	100	-	-
Houston Belt & Terminal Ry.	25	25	100	-	-	-	-	-	-
Illinois Terminal RR	41	41	100	-	-	-	-	-	-
Indiana Harbor Belt RR.	106	106	100	-	-	-	-	-	-
Kansas City Terminal	10	10	100	-	-	-	-	-	-
Lake Superior & Ishpenning RR	23	-	-	7	30.4	16	69.6	-	-
Lamallie Valley	7	-	-	-	-	7	100	-	-
Louisiana & North West RR	8	8	100	-	-	-	-	-	-
Main Central Railroad	37	25	67.6	10	27	2	5.4	-	-
Manufacturers Railway	11	3	27.3	-	-	8	72.7	-	-
Manufacturers Junction Ry.	2	2	100	-	-	-	-	-	-
Michigan Northern Railway	10	10	100	-	-	-	-	-	-
Minneapolis, Northfield & Southern Ry.	10	10	100	-	-	-	-	-	-
Monangahela Ry.	11	11	100	-	-	-	-	-	-
New Hope & Tryland	7	-	-	2	28.6	-	5	71.4%	-
New York Dock Railway	8	2	25	-	-	6	75	-	-
New York Susque & West	16	3	18.8	-	-	13	81.2	-	-
Norfold & Portsmouth	15	15	100	-	-	-	-	-	-
Providence & Worcester RR	13	3	23.1	2	15.4	8	61.5	-	-
Richmond, Fredericksburg & Potomac RR	38	38	100	-	-	-	-	-	-
Roscoe Snyder & Pacific	2	2	100	-	-	-	-	-	-
Sabine River & Northern	3	3	100	-	-	-	-	-	-
Seattle & North Coast RR	3	3	100	-	-	-	100%	-	-
Tennessee Valley Railroad	5	-	-	-	-	5	-	-	-
Terminal Railroad Assoc. -St.Louis	14	14	-	-	-	-	-	-	-
Texas Mexican Ry.	16	16	100	-	-	-	-	-	-
Texas Southern Railroad	3	-	-	2	66.7%	-	-	1	33.3%
Toledo, Peoria & Western RR	29	23	79.3	-	-	6	20.7	-	-
Union RR	126	124	98.4	-		2	1.6	-	-
Utah Ry.	11	-	-	-	-	11	100	-	-
Vermont Ry.	7	4	57.1	-	-	3	42.9	-	-
Washington Terminal Co.	8	2	25	-	-	6	75	-	-
Western Ry. of Alabama	18	18	100	-	-	-	-	-	-
Total	1135	959	84.5%	28	2.5%	142	12.5%	6	.5%

RAILROAD	TOTAL	%	GMC	%	GE	%	MLW/BBD	%	OTHERS
Abitibi Price Inc.	1		-		-		1	100	-
Aluminum Company of Canada	14		-		-		14	100	-
British Columbia Railways	21		21	100	-		-		-
Johns-Manville	9		-		-		9	100	-
Greater Winn. Water District	4		-		4	100	-		-
Inco Metals	1		1	100	-		-		-
Kidd Creek	3		-		-		3	100	-
TOTAL	53	100	22	41.5	4	7.5	27	51	-

Note: Locomotives with maximum 2000 HP

TABLE 5

INDUSTRIAL RAILROADS - CANADA

LOCOMOTIVE FLEETS
AND BUILDERS

RAILROAD	TOTAL	%	EMD	%	GE	%	ALCO	%	OTHERS
Allegheny Ludlum Steel	1		-		1	100	-		-
Armco Middletown	25		25	100	-		-		-
Bethlehem (South Buffalo RR)	29		-		-		29	100	-
International Mineral & Chem.	6		-		-		6	100	-
Mobay Chemical Corp.	1		-		-		1	100	-
TOTAL	62	100	25	40.3	1	1.6	36	58.1	-

Note: Locomotives with maximum 2000 HP

TABLE 6

INDUSTRIAL RAILROADS - USA

LOCOMOTIVE FLEETS
AND BUILDERS

RAILROAD	TOTAL	%	EMD/GMD	%	GE	%	ALCO	%	OTHERS	%
Gov. of Ontario Transit	30	100	30	100	-		-		-	
Long Island RR	91	100	62	68.1	2	2.2	27	29.7	-	
Maryland Dept. of Transport	5	100	5	100	-		-		-	
Mass. Bay Transport Auth.	38	100	38	100	-		-		-	
State of New Jersey Dept. of Transport	80	100	48	100	32	40	-		-	
Port Auth. of Allegheny Cty	2	100	2	100	-		-		-	
Regional Transp. Auth.	145	100	145	100	-		-		-	
Southeastern Mich. Transport Authorities	5	100	5	100	-		-		-	
TOTAL	396	100	335	84.6	34	8.6	27	6.8	-	

TABLE 7

NON-CLASSIFIED RAILROADS - TRANSIT SYSTEMS & AUTHORITIES

LOCOMOTIVE FLEETS
AND BUILDERS

RAILROAD	TOTAL	%	EMD	%	GE	%	ALCO/MLW/BBD	%	OTHERS	%
National Ry of Mexico	1475	100	504	41	548	37	323	22	-	-
Pacific RR	153	100	-	-	41	26.8	101	66	11	7.2
Sonora-Baja California Ry	23	100	23	100	-	-	-	-	-	-
United Southeastern Ry	46	100	25	54.3	3	6.6	18	39.1	-	-
Chihuahua Pacific Ry	58	100	51	88	-	-	-	-	-	-
TOTAL	1755	100	703	40.1	592	33.7	442	25.2	18	1

TABLE 8

NON-CLASSIFIED RAILROADS - MEXICO

LOCOMOTIVE FLEETS
AND BUILDERS

BY RAILROAD CLASSIFICATION

	TYPE OF RAILROAD	TOTAL	%	GM	%	GE	%	ALCO/MLW/BBD	%	OTHERS	%
5	Class I Canadian	3641	100	2587	71.05	0	30.90	1051	28.86	-	-
6	Class I U.S.	27712	100	23579	85.40	3624	13.10	391	1.40	18	0.10
7	Class II-III Canadian	286	100	212	74.10	13	4.60	61	21.30	-	-
8	Class II-III U.S.	1135	100	959	84.50	28	2.50	142	12.50	6	0.50
9	IND.RR Canadian	53	100	22	41.51	4	7.55	27	50.94	-	-
10	IND.RR U.S.	62	100	25	40.32	1	1.61	36	58.06	-	-
11	Unclass. Mex.	1755	100	703	40.10	592	33.70	442	25.20	18	1.00
12	Transit systems	396	100	335	84.60	34	8.60	27	6.80	-	-
		35040	100	28522	81.40	4299	12.27	2177	6.21	42	0.12

BY GEOGRAPHICAL AREA

PROPORTION	AREA	TOTAL	%	GM	%	GE	%	ALCO/MLW/BBD	%	OTHERS	
11.36%	CANADA	3980	100	2821	70.9	20	.48	1139	28.62	-	-
83.53%	U.S.A.	29305	100	24998	85.3	3687	12.58	596	2.03	24	0.09
5.01%	MEXICO	1755	100	703	40.1	592	33.7	442	25.50	18	1.0

TABLE 9

DISTRIBUTION OF ALL NORTH AMERICAN LOCOMOTIVES

HP	EMD	GE	ALCO	MLW	BBD	GMD	OTHERS(1)	ALL
ALL Power ranges (*)	17814	2189	655	841	109	1652	1097	24357
Average age (years)	19.76	11.88	26.71	22.7	4.44	20.68	11.64	18.97
Percentage of fleet	73%	9%	2.7%	3.5%	5%	6.8%	4.5%	100%
HP 1000 (KW 746)	427	18	25	54	-	109	39	671
Average age	32.32	38.33	26.68	27.8	-	30.38	27.83	31.35
Percentage of fleet	63.5%	2.7%	3.7%	8.0	-	16.25%	5.75%	100%
1000 HP 1200 (746 KW 895)	813	-	125	162	-	4	54	1158
Average age	33.48	-	31.99	27.31	-	23.5	34.95	32.49
Percentage of fleet	70.2%	-	10.8%	14.0%	-	.35%	4.65%	100%
1200 HP 1500 (895 KW 1119)	5798	9	138	-	-	375	133	6453
Average age	22.0	51.33	32.85	-	-	25.07	48.62	23.0
Percentage of fleet	89.8%	.1%	2.2%	-	-	5.8%	2.1%	100%
1500 HP 2000(1119 KW 1491)	6088	165	250	526	30	790	742	8591
Average age	17.96	10.44	22.84	21.51	6.33	22.07	9.71	17.8
Percentage of fleet	70.9%	1.9%	2.9%	6.2%	.4%	9.2%	8.5%	100%
2000 HP 2500(1491 KW 1864)	2204	1232	85	99	56	27	3	3706
Average age	19.32	10.74	20.04	18.8	4.00	19.59	5.96	16.23
Percentage of Fleet	59.5%	33.2%	2.3%	2.7%	1.5%	.7%	.1%	100%
2500 HP 3000(1864 KW 2237)	6	119	-	-	23	-	4	152
Average age	4.0	18	-	-	3.09	-	6.17	14.88
Percentage of fleet	3.9%	78.3%	-	-	15.2%	-	2.6%	100%
HP= 3000 (KW = 2237)	2133	460	12	-	-	307	-	2912
Average age	11.85	11.93	17.58	-	-	9.94	-	11.69
Percentage of fleet	73.2%	15.8%	.4%	-	-	10.6%	-	100%
3000 HP 3500(2237 KW 2610)	277	28	-	-	-	-	-	305
Average age	4.38	16.0	-	-	-	-	-	5.44
Percentage of fleet	90.8%	9.2%	-	-	-	-	-	100%
3500 HP (2610 KW)	47 (2)	133	-	-	-	-	-	180
Average age	4.0	11.38	-	-	-	-	-	9.45
Percentage of fleet	26.1%	73.9%	-	-	-	-	-	100%

(*) includes slug units

(1) includes units built by the railroads & miscellaneous builders

(2) electric units

TABLE 10

TYPES AND AGE OF LOCOMOTIVES WITH WHEEL ARRANGEMENT B-B, ALL HP RANGES

2.3 Customer Survey

One of the most important tasks of the switcher study project was to conduct a customer survey in order to establish detailed information regarding the existing locomotive population in North America and to obtain sufficient information from selected operators for the preparation of a new locomotive specification.

The scope of the information required and the large number of North American users made the task quite formidable. A decision was made to proceed initially with a printed questionaire to be mailed to a selected number of railroads considered as representative of a cross-section of all North American users.

This was followed by personal contacts and visits to the operating and mechanical departments of a limited number of users in order to obtain more definitive information on present and future operating methods including design features and performance criteria which they would consider desireable when contemplating future equipment purchases.

The questionnaire was designed with the minimum of questions to keep the forms as simple as possible thus gaining an anticipated high rate of return. A section was included regarding statistical information on the present locomotive fleet. An accompanying letter explained the purpose of the survey, the information sought and guidelines on how to fill in the statistical section. To simplify matters further a postage-paid envelope was included. Despite all these advance preparations the questionnaires returned must be considered a disappointment and could not be treated as conclusive evidence in preparing a set of specifications. Nevertheless the data that was received was useful as reference information.

It appears that the majority of railroads regarded these forms as a record for their own present locomotive fleet rather than a basis for a future design. Moreover most of the forms were incomplete and a few were not legible at all. The section "Comments", intended to describe desired specific auxiliary equipment, was not filled in on the majority of questionnaires returned. Only 14.4% of all returns contained sufficient information to be useful statistically.

The visits proved to be much more productive and provided a substantial insight into the expectations of the operating and mechanical departments of those railroads that could be visited within the time and funds available.

Table 11 shows the number of visits made and responses to the questionnaires arranged according to the various types of railroads.

TYPE RAILROADS	VISITS	QUESTIONNAIRES MAILED QTY	TOTAL RR CONTACTED QTY	QUESTIONNAIRES RETURNED QTY	%	QUESTIONNAIRES COMPLETED QTY	%
Class I Canadian	2	2	4	2	100	1	50
Class I USA	10	22	32	8	36.4	3	13.6
Short Haul Canadian	-	12	12	5	41.7	3	25
Short Haul USA	3	128	131	39	30.5	3	10.9
Industrial Canadian	-	9	9	7	77.8	5	55.6
Industrial USA	-	29	29	10	34.5	4	13.8
TOTAL	15	202	217	71	35.1	29	14.4

TABLE 11

QUESTIONNAIRE RESPONSES

AND VISITS

Information obtained from the visits suggested that four different types of locmotives are engaged in North American switching operations:

- Switcher units (low hood units designed specifically for yard use).

- Road switcher units (high hood units designed for road use but capable of switching assignments).

- Transfer units (road switchers designed for short haul regional interconnection service).

- Hump units (locomotives assigned for low-speed train pushing service).

Switcher units are generally quite satisfactory for performing switching functions in yards to include rapid response in order to "Kick" or otherwise move cuts of cars. These units do not usually have all the equipment required (silencer, toilet, signaling equipment, etc.) in order to run as a road switcher on the main line.

Road switchers can enter yards and sidings and carry out their own switching operations although with somewhat handicapped visibility in the long hood direction. Transfer locomotives, would, in fact, be expected to efficiently carry out this function during a large portion of their working day.

Hump duty is a specialized operation normally carried out using older locomotives modified for very low speed operation. Such locomotives, once modified by a re-builder or the railroad, never see main line service again.

Locomotive builders have been developing motive power improvements in order to offer new models with superior performance to include increased fuel efficiency. Practically all of this effort has been concentrated on higher-power road locomotives where there is a strong, immediate economic incentive. This, in turn, has resulted in older road units being downgraded to transfer or yard service, often without any additional investment whatever. Many railroads have established facilities for rebuilding locomotives and, in some cases, the rebuilds are performed using retrofitable improvement packages obtained from the builders. Some of the builders have been offering "trade-in" allowances and will accept old locomotives either for scrap or as a chassis upon which to rebuild with new equipment. Salvage companies also often buy up old locomotives for resale to industrial and short-line railroads.

Although it would appear that the combined effect of the motive power exchanges, transfers, rebuilds, resales, etc. mentioned above would effectively supply the switcher and even the transfer locomotive market, this is not necessarily the case. While it is evident that the major builders are not emphasizing switching units in their current new model offerings, there have been recurring indications that an all-new locomotive could be attractive to the railroads providing it can stand up to all their economic viability criteria.

This new design must address all the requirements usual for this type of locomotive specification while retaining sufficient flexibility to accommodate a variety of easily-applied options. A standard prime mover, enjoying commonality with other types of locomotives, plus a modular approach using standardized components and systems must be employed to maximize standardization on the customer's property and reduce manufacturing cost. The traction system will be chosen to work to a high level of adhesion utilization and micro-processor controls will be used to optimize efficiency of on-board systems.

The degree of operating success achieved by this new design will determine to a large extent the nature and size of the anticipated market for a general-purpose locomotive in the specified power range.

Information received from motive power users during the market survey has been used in the preparation of a preliminary locomotive specification (Section 3). In regards to the specification, the following general comments are applicable.

While innovation is recognized as essential to progress, the specification respects the generally conservative view-point of most railroad mechanical department people encountered in the process of obtaining data. The prevailing attitude is that components and systems will not be readily accepted unless they have been subjected to extensive service and thereby proven reliable. Most operators, however, also readily recognize that new major mechanical and electronic improvements must be incorporated to achieve the expected efficiency and performance levels. The skill with which the new is blended with already proven equipment, and the security offered by reliable back-up systems should lessen the reluctance of the railroads to accept new locomotives so-equipped and to commit such locomotives to unrestricted service. It is only in this way that sufficient reliability statistics will be obtained so that the builder can satisfactorily assess his design and complete the development cycle.

The power transmission system and the diesel engine, together with their associated controls, are the critical elements of every locomotive concept. The running gear and the auxiliary equipment follow next in importance since they are both involved in reliably producing the desired traction performance. The packaging of all this equipment in a suitable envelope to ensure maximum access=bility and quick change-out of modular components and systems is also mandatory to keep maintenance cost and out-of-service time to a minimum. These factors apply regardless of the type of service for which a locomotive is designed.

Locomotive cabs and driving controls have evolved slowly over the years with the location and movement of propulsion (throttle) and braking control levers being generally retained as in steam locomotive days.

Labor laws and environmental considerations in recent years have resulted in structural improvements to locomotive cabs and an ergonomically-motivated study of driver's controls to make the locomotive operator's work place more efficient and substantially safer than in the past. Elimination of cabooses and reduction in the size of train crews, a movement which is now gaining momentum, can have a significant effect on the size and shape of operator's cabs. These factors, when combined with the needs identified in this study, particularly with respect to improving driver visibility, result in a requirement for new cab configurations that differ functionally from the conventional switcher cab and provide the locomotive with a new external appearance.

3. LOCOMOTIVE SPECIFICATION

3.1 General Information and Identification

Type: AAR designation B-B.

3.1.1 Arrangement

The basic locomotive shall consist of one unit complete with engine, alternator, trucks and all necessary equipment for single unit operation.

3.1.2 Nominal Dimensions

Width over cab	- 3048 mm	(10' 0")
Maximum width of locomotive	- 3124 mm	(10' 3")
Maximum height of locomotive	- 4724 mm	(15' 6") maximum

3.1.3 Weight and Supplies

Total loaded:	Maximum	- 133812 kg	(295,000 lb)
	Nominal	- 117936 kg	(260,000 lb)
	Minimum	- 104328 kg	(230,000 lb)
Fuel capacity		- 5900 l	(1300 gal)
Sand capacity		- 1000 l	(35 ft^3)

3.1.4 Clearances

Locomotive to pass AAR plate "B".

3.1.5 Safety Appliances

All steps, grab handles and safety appliances shall be to Interstate Commerce Commission and Canadian Transport Commission requirements.

3.1.6 Curve Negotiation

Truck swing shall allow single unit to negotiate curve with radius of at least 30.5 m (100 ft) or 57°curve. Single unit coupled to a 15 m (50 ft) car shall be capable of negotiating a 92 m (302 ft) radius curve or 19°.

Two units coupled in multiple shall be capable of negotiating a 59 m (193 ft) radius curve or 30°.

3.1.7 General Requirements

Locomotive shall conform with AAR, FRA, ICC, CTC, and EPA requirements.

3.2 Carbody construction

3.2.1 Frame

Underframe shall be of all-welded construction consisting of two main center sills, carrying members for hoods, power plant, equipment, and walkways.

3.2.2 Collision Posts

Collision structure shall be an integral part of the short hood (transfer locomotive configuration); in absence of such (switcher locomotive configuration) an integral part of the cab front wall.

3.2.3 Bolster Centre

Depending on truck applied, provision shall be made for bolted or welded center post to underframe.

3.2.4 Jacking pads

Combination jacking pads and cable slings shall be provided at each side of bolster.

3.2.5 Couplers

Couplers shall be Type "E", self-aligning. Maximum free swing either side: 8°. Maximum swing either side: 17°.

3.2.6 Draft Gear

Draft gear shall be National Casting rubber type including alignment control and assembled with yoke.

3.2.7 Uncoupling Device

Each end of locomotive shall be provided with an operating device arranged to unlock the coupler from the ground or from the bottom step. Uncoupling device formed from one piece.

3.2.8 Platform Step

Steps and an appropriate stairwell arrangement shall be provided at each corner leading onto the locomotive platform and to the walkways.

3.2.9 Cab

The operator's cab shall be of welded steel construction lined with thermal and acoustic insulation. Stationary heated windows are applied at the front and rear. Sliding type unheated windows applied on both sides. Doors are located on both sides leading to the catwalks and one door provides access from the front.

3.2.10 Windows

All windows shall conform with the latest FRA Class I & II regulations.

3.2.11 Insulation

Cab shall be insulated against noise and heat losses whereby the maximum allowable noise level in cab shall not exceed 80 decibel with engine running under full load and locomotive at maximum speed.

3.2.12 Battery Boxes

The battery boxes, containing lead-acid or nickel-cadmium batteries, shall be located on either side of hoods along walkways.

3.2.13 Hoods

All hoods shall be of modular design. The radiator compartment shall contain the radiators, shutters and cooling fans. The radiators shall be either side or roof mounted depending on the fan arrangement. A section shall hold the sand boxes, accessible from the roof. Back-up lights and number boxes shall be mounted on the end of the hood.

The engine hood shall enclose the engine, to which complete access shall be provided by doors extending along both sides of the locomotive. Doors in the roof shall provide overhead access to engine cylinders. Detachable roof sections will be required to permit removal of equipment.

A separate auxiliary hood shall enclose the equipment located between the engine and the cab.

3.3 Trucks

3.3.1 Truck Assembly

Two truck assemblies of the 4-wheel type shall be provided per locomotive, and are to be interchangeable with each other. The truck frame shall be supported on each of the four journal boxes by coil springs.

Traction motors shall be series type DC or suitable squirrel-cage induction 3-phase AC. For DC traction an individual motor shall be used for each axle driving through a single-reduction gear box. Alternately, a higher-speed 3-phase AC induction motor may be applied at each axle driving through a double-reduction gearbox. Motor must be suitable for mounting in conventional and steering-type trucks. Gearboxes shall be designed for increased reliability and maintenance periods (at least 92 days). Fine pitch gearing shall be used if necessary to reduce vibration and eliminate scuffing. Gear cases shall incorporate traction motor air inlet plenums to protect motors in winter operation.

3.3.2 Journal Boxes

Journal boxes shall be standard Bombardier design using roller bearings.

3.3.3 Wear Plates

Lateral: Manganese steel plates.
Pedestal: Nylatron liners.

3.4 Engine and Transmission

3.4.1 Engine

The engine shall be diesel type, 4 stroke, inline 6 or V-8, turbocharged, with power for traction as follows:

Inline 6: 746 KW - 1343 KW (1000 HP - 1800 HP).
V-8 : 1343 KW - 1791 KW (1800 HP - 2400 HP).

3.4.2 Governor

Variable speed model shall be applied.

3.4.3 Overspeed Protection

Mechanical device shall return injection pumps to 'No Fuel' setting in the event of engine overspeed.

3.4.4 Engine Start

Electric or pneumatic engine starters acting on the crown gear of the alternator fan shall be used.

3.4.5 Engine Protection

Provision shall be made to shutdown the engine during all seasons in order to save fuel. Protection shall be provided by applying auxiliary electric pumps and heaters to circulate water, oil and/or fuel. The pump shall be driven by a small diesel engine or electric motor enabling the engine to be restarted even in sub-zero condition. Provisions for connection to wayside power shall be available on the locomotive.

Alternatively, a low idle mode may be provided for the diesel engine. In this case automatic drain and refill of the radiator system shall be provided.

3.4.6 Fuel System

An electrically-driven transfer fuel pump shall be provided to supply fuel from the fuel tank to the engine injector pumps. A filter shall be applied on the pressure line. A hot-well shall be constructed in the fuel tank and a heat exchanger with automatic mixing valve shall be provided. Filters to prevent dirt from being drawn into the system shall be furnished.

3.4.7 Cooling System

The diesel engine shall be cooled by air, oil and water. All electrical equipment shall be cooled by air, directly or by means of appropriate heat exchangers.

3.4.8 Engine Water System

Engine water shall be cooled by top or side-mounted radiators. Standard safety and alarm system shall be provided. Strainers shall be applied to protect mechanically-bonded radiators. Temperature switches shall be of the 'Sunstrand' design.

3.4.9 Engine Lubricating System

A water-cooled lube oil cooler shall be applied. Lube oil filters shall be designed for 92 days minimum maintenance period.

3.4.10 Engine Air Filter

Primary filtering shall be by fiberglass disposable panel filters, or inertial type separators. Secondary filtering shall be AAF bag type filters, Farr Dynacell or fiberglass.

3.4.11 Engine Exhaust

A silencer shall be applied, if required, to meet EPA or U.S. State Law regulations. Exhaust fumes shall not be drawn back into air systems. The stack shall protrude a minimum of 50 mm (2") above the cab roof.

3.4.12 Cooling System Air

Three separate electrically-driven blowers shall be provided. One blower shall supply the front traction motor cooling air, the second shall supply the rear traction motor, and a third shall cool the control compartment, rectifier, and traction inverters (if used).

Air shall be filtered by either disposable fiberglass filters or inertial-type air separators. The blower drives shall allow adjustment of air flow independent of engine speed in order to allow reduction of air flow in the winter. The main alternator shall incorporate its own cooling fan.

3.4.13 Main Alternator

The main alternator shall be directly connected to and driven by the diesel engine. It shall supply 3-phase alternating current to the rectifier for traction power.

3.4.14 Auxiliary Alternator

The auxiliary alternator shall be built into the main alternator. It shall supply power for locomotive auxiliaries to include battery loads and charging, radiator fan and blower drives, and excitation.

3.4.15 Radiator Cooling Fan Drives

Depending on engine power capability, either one or two cooling modules shall be provided. Each module shall be cooled by two electric motor driven cooling fans mounted in a side-by-side arrangement.

3.4.16 Propulsion Control

The control system shall consist of solid state hardware mounted on individual removable plug-in cards. Microprocessors shall be used to control excitation, logic, diagnostics and displays. The engine shall follow an 8-notch speed schedule. Alternately, the engine may have modulated speed capability depending on traction and auxiliary load.

3.5 Air Brake Equipment

3.5.1 Air Brakes

The air brake equipment shall be schedule 26L with provision for unitized and panel-mounted assemblies.

3.5.2 Foundation Brakes

Provision shall be provided for both 203 mm (8") and 254 mm (10") brake cylinders utilizing a single shoe brake arrangement or clasp brake.

3.5.3 Air Compressor

Air compressor shall be a piston type, 200 CFM minimum capacity, three cylinder, two stage, water cooled, for direct drive from the engine.

A clutch shall be provided for disengagement when further air is not required.

Disposable intake air filters shall be provided.

The oil sump shall be of large capacity.

3.5.4 Air Reservoirs

Two air reservoirs shall be provided and located below the underframe. Total capacity to be 1000 liters (61,000 cu in).

3.6 Auxiliary Equipment

3.6.1 Cab Heating and Ventilation

Electrical cab heaters shall obtain filtered fresh air from outside the locomotive. The heating system shall maintain cab temperature at 21°C (70°F) with an ambient temperature of -40°C (-40°F) at maximum locomotive design speed.

3.6.2 Cab Seats

Seats shall be provided for a minimum of 3 and a maximum of 5 people.

3.6.3 Control Stand

A simplified, ergonomically-designed control stand with integrated microprocessor-based instrumentation and communications, suitable for equivalent ease of operation in either locomotive direction, shall be provided.

3.6.4 Defroster

Defrosting shall be provided for front and rear windows.

3.6.5 Headlights

Two 200 watt, sealed beam headlights shall be furnished at both the front and rear ends of the locomotive.

3.6.6 Safety Equipment

New safety rules are in preparation by FRA regarding warning lights (strobe lights). Two additional headlights of the oscillating type mounted low on the left and right sides may be required.

6.6.7 Sand Boxes

Sand boxes shall be provided at the front and rear of the locomotive with a maximum total capacity of 1000 liters (35 ft^3). Boxes shall be designed to prevent ingress of moisture and attached to underframe.

3.7 Customer Options

The following options may be selected:

1. Air conditioning
2. Auxiliary power supply for calf unit
3. Additional cab seats
4. Ditch lights
5. Dynamic brake, incl. self-test feature and extended range
6. Fuel oil heater
7. Hot plate
8. Pacesetter control
9. Refrigerator
10. Snowplow
11. Strobe Light
12. Toilet
13. 44 in. (1120 mm) wheels

4. COMPONENT ANALYSIS

4.1 General

Based on the specification established for the switcher locomotive, several major components required further analysis in order to determine equipment requirements. Alternatives were investigated in some cases and will be discussed in this section. The components researched were as follows:

- Transmission
- Prime mover
- Trucks
- Cooling system
- Auxiliary equipment
- Air brake equipment.

Conventional equipment as well as emerging new technology were reviewed. The switcher locomotives presently in operation were designed 30 years ago; since then, technology has advanced tremendously, especially in Europe and Japan.

The equipment judged most suitable to the application was adopted for use in the locomotive layouts. Options are available for those operators requiring more conventional equipment.

4.2 Transmission

4.2.1 General Requirements

The diesel engine is a constant power device with a well-defined speed/torque characteristic for a given fuel setting. The available engine torque is generally much lower than the torque required at the driving wheels of a locomotive.

For this reason and because the engine is separated from the axles by considerable distances involving movements across at least two spring systems, a transmission system is a necessity on a locomotive.

The major functions of the locomotive transmission system are as follows:

- Convey torque from the engine to the driven axles (transmission function).

- Increase the torque at the axle in order to realize sufficient locomotive tractive effort (gear reduction function).

- Provide decoupling from the engine; enabling, for example, the engine to idle without locomotive movement (coupling function).

- Provide an approximate match between required torque/speed performance at the rail to that available from the engine (gear-change function).

- Allow the locomotive to work in an identical manner in both directions (reversibility function).

A number of transmission concepts have been developed and applied to switcher locomotives in order to satisfy the above requirements. They can be catagorized into groups according to the physical means of transmitting power:

- Mechanical
- Hydraulic
- Electric

In the following sections the various transmissions will be described briefly and their applicability to North American switcher locomotives presented.

4.2.2 Mechanical Transmissions

The simplest and most efficient transmissions are of the mechanical type. These include chain, belt, and shaft arrangements designed to convey the engine power to the driven axles. The torque is increased by different size sheaves (belt drive), sprockets (chain drive), or gears (shaft drive).

A decoupling device must be provided in some form to allow engine idling in a stopped locomotive and to enable gear (or sprocket) changes. Belt drives, while offering the possibility of continuously variable torque adjustment, are limited to very low power (approximately 100 HP) and would be too susceptible to environmental factors to work satisfactorily on a locomotive. They will, therefore, not receive further consideration.

Chain drives are capable of higher levels of power transmission 200-400 HP) but can be subject to rapid wear considering their need for lubrication and their open construction. Chain drives, in addition, have a limited operating speed and require a tensioning device. Where trucks are involved, as opposed to rigid frame locomotives, the transmission problems are compounded. For these reasons chain drives are dismissed from further consideration for North American switcher applications.

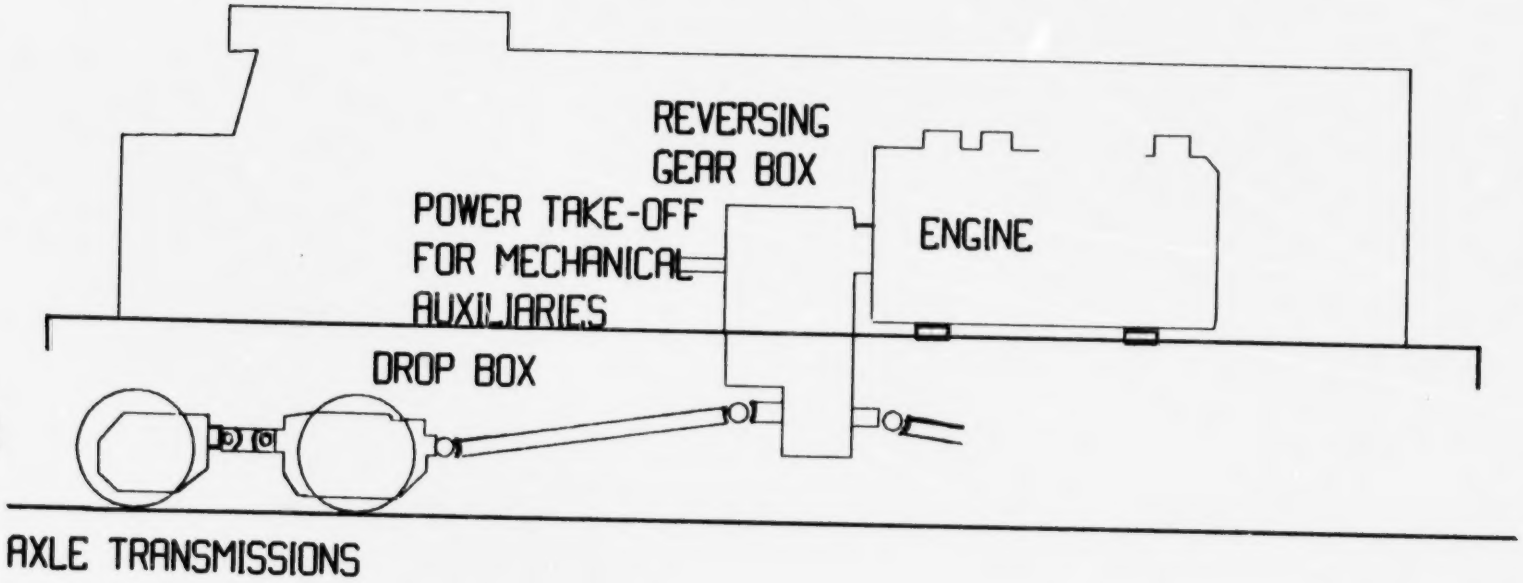


FIG. 1

MECHANICAL TRANSMISSION

The mechanical drive consisting of gearboxes and shafting is feasible at all power levels and has often been applied to various types of locomotives throughout the world. A schematic representation is shown in Figure 1.

Engine torque is transmitted through a clutch (typically electrically operated) into a gear box. The gear box has the function of providing the number of gear changes required to match the engine speed/torque characteristic to the locomotive requirements, as well as to allow operation in both directions.

A number of shafts equipped with appropriate couplings are required. The couplings must accommodate the relative motions of all the components involved.

The connections below the locomotive deck are inherently torsionally very stiff ensuring that all axles turn at the same speed and single axle slip/slide becomes impossible. If, however, the wheel diameters are not identical, locked-in-torques will develop and result in the larger wheels carrying more than their share of the tractive load. This will result in significantly increased rolling resistance until the wheels wear to the same diameter.

The only practical locomotive layout for this type of transmission requires placement of the engine over a truck with the gearbox projecting through the floor at the center of the locomotive and feeding to both trucks. The gearbox and shafts underneath the locomotive floor are not compatible with normal North American fuel tank arrangement practices.

A second engine may be added over the remaining truck with connection to a second gearbox. This usually leads to placement of the cab at the center of the locomotive - a satisfactory arrangement for switching purposes since this offers excellent visibility in all directions. Acceptance of such a configuration for transfer duties would be questionable, however; preference usually being given to an arrangement with a short leading hood.

The straight mechanical transmission would probably be too rough in regard to engine loading transitions to allow satisfactory service in excess of 500 to 600 HP; beyond this power level hydrokinetic components would be included.

4.2.3 Hydrokinetic Transmission

The hydrokinetic transmission works by means of a high velocity fluid stream transmitting power. When configured as a fluid coupling

with the impeller connected to the engine and the turbine to the output shaft, the fluid will transmit a constant torque across the coupling. The power transmitted will depend on the relative speeds of the impeller and turbine. This allows the locomotive to be accelerated from a stop or following a gear change without engine lugging, although a very poor efficiency would exist during the time required for the speeds across the coupling to equalize.

The efficiency of the transmission can be increased under these conditions by configuring the coupling as a torque converter. At locomotive start and following gear changes, the engine torque is multiplied by approximately 2.0 to 5.0, thus allowing the power transmission efficiency across the converter to reach 90% at a speed ratio of approximately 70%. The torque converter can be reconfigured into a fluid coupling at this point and the efficiency will continue to rise as the speed difference decreases until 95% is reached at unity speed ratio.

When operated in the above manner, the torque converter/gearbox arrangement provides a reasonable match to the engine speed/power capabilities. A North American switcher locomotive designed for a full speed range would require an 8-speed reversing gearbox in addition to the torque converter.

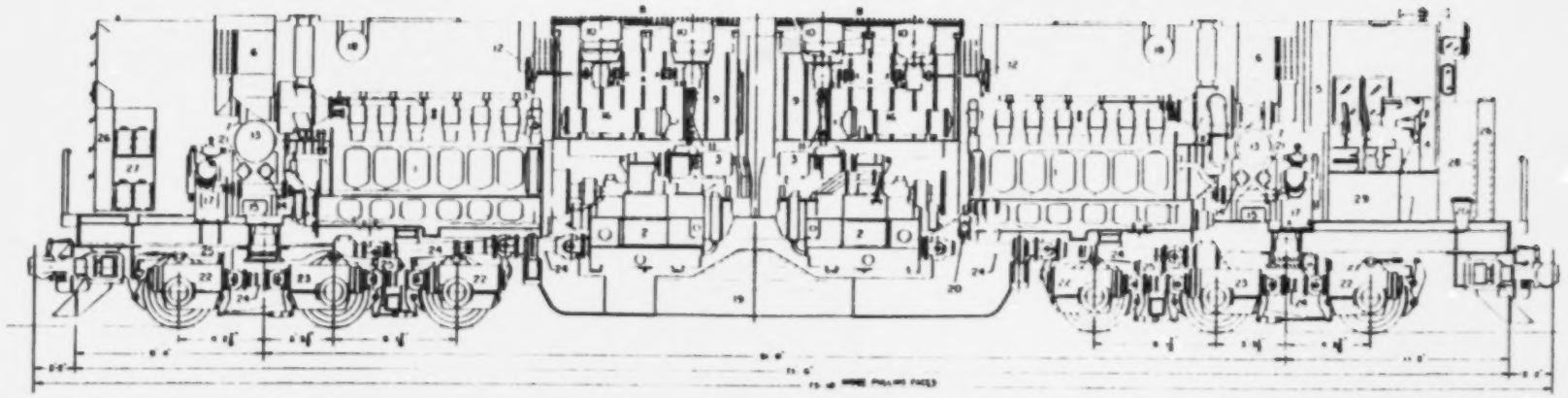
The transmission can also be designed such that hydraulic components assume the gear shift and reversing functions. A number of torque converters would be provided in this case and a filling/emptying scheme employed to effectively change the gear ratio and direction of travel. This configuration as actually built as shown in Figure 2 for a series of ALCO 2-engine road locomotives. A wide variety of mixed mechanical/hydraulic schemes have also been devised and successfully applied to locomotives around the world.

Common to all configurations, however, is the mechanical axle drive and the equipment placement requirements, both above and below the locomotive frame, inherent to this drive.

The hydrokinetic transmission has not succeeded in penetrating either the North American railroad or industrial market except in a few scattered instances. The reason for this appears to be in its perception as a "delicate", foreign technology requiring specialized and expensive maintenance practices. This is not the case, as such transmissions have proven themselves under adverse conditions worldwide with only minimal maintenance attention.

Another possible explanation has to do with the overwhelming volume production of electric transmissions in North America, leading to a disadvantageous cost situation for diesel-hydraulic locomotive transmission components.

ALCO DH-643



1. Engine
2. Hydraulic Transmission
3. Auxiliary Generator
4. Control Stand
5. Electrical Control Equipment
6. Mechanical Air Cleaner (Engine Air)
7. Air Cleaner Exhauster
8. Engine and Transmission Cooling Unit
9. Radiator
10. Radiator Fan
11. Radiator Fan Drive Shaft
12. Radiator Shutter
13. Lubricating Oil Filter
14. Lubricating Oil Strainer
15. Lubricating Oil Cooler
16. Transmission Oil Heat Exchanger
17. Air Compressor
18. Main Air Reservoir
19. Fuel Tank
20. Fuel Tank Filling Connection
21. Fuel Oil Filter
22. Axle Gear Box
23. Axle Gear Box - Intermediate
24. Cardan Shaft
25. Torque Reaction Arm
26. Sand Box
27. Batteries
28. Hand Brake
29. Brake Equipment

FIG. 2

HYDRAULIC TRANSMISSION

It can thus also hardly be expected of the larger North American locomotive manufacturers, who manufacture their own electrical equipment, to encourage the market to accept diesel-hydraulics, especially in view of the complete locomotive redesign which would be required with this technology.

4.2.4 Hydrostatic Transmission

In a hydrostatic transmission system, the diesel engine drives a positive displacement hydraulic pump, usually of the piston type, which supplies high pressure hydraulic fluid via a system of piping and hoses to axle-mounted hydraulic motors. The hydrostatic transmission system can readily duplicate the performance of an electric transmission system in the high tractive effort low-speed operating region of a locomotive but becomes impractical if higher locomotive speeds are also required because of viscosity and vapor pressure considerations in the hydraulic fluid.

4.2.5 Electric Transmissions

4.2.5.1 General Considerations

All electric transmission schemes must carry out the following functions:

- Convert diesel engine mechanical power into electric power
- Control the electric power
- Transmit the electric power to the traction motors
- Convert the electric power into tractive effort and movement of the locomotive and its train.

An alternator is now usual in North America for generating the electric power. The three phase AC output power from the alternator is connected to a full-bridge rectifier to produce direct current.

The design of the alternator and rectifier are dependent on the type of motor to be used. The motor may be one of the following types:

- DC
- 3-phase AC syncronous
- 3-phase AC asyncronous

The 3-phase AC motor alternatives may further be of rotary or linear construction.

Linear motors require, a reaction rail on the trackbed and can, therefore, only be considered for very special applications.

Restricting further consideration to the rotary machine, there are a number of possible arrangements for mounting the traction motors in the trucks:

- Transverse motor driving each axle

- Single transverse motor driving both axles

- Longitudinal motor driving each axle

- Single longitudinal motor driving both axles

The arrangements using a single motor to drive both axles automatically provide a very stiff coupling between axles and therefore eliminate any risk of individual axle slip. The motor is elastically mounted in the truck and thus removed from the axle shock environment. Couplings are required to accommodate axle motions. Locked-in torques with consequent rapid wheel wear and excessive fuel consumption can result if wheels are not of the same diameter.

Designs providing for use of a single motor lead to placement of the motor in the center of the truck. This will necessitate major changes to the present truck structure and locomotive underframe attachments. The resulting non-standard trucks and attachments would be undesirable to the railways as would the close attention required on wheel diameters.

Truck changes are also unavoidable if the use of two longitudinal motors is envisioned; the length of the motor plus the required couplings would require removal or perforation of the transom in order to install the equipment.

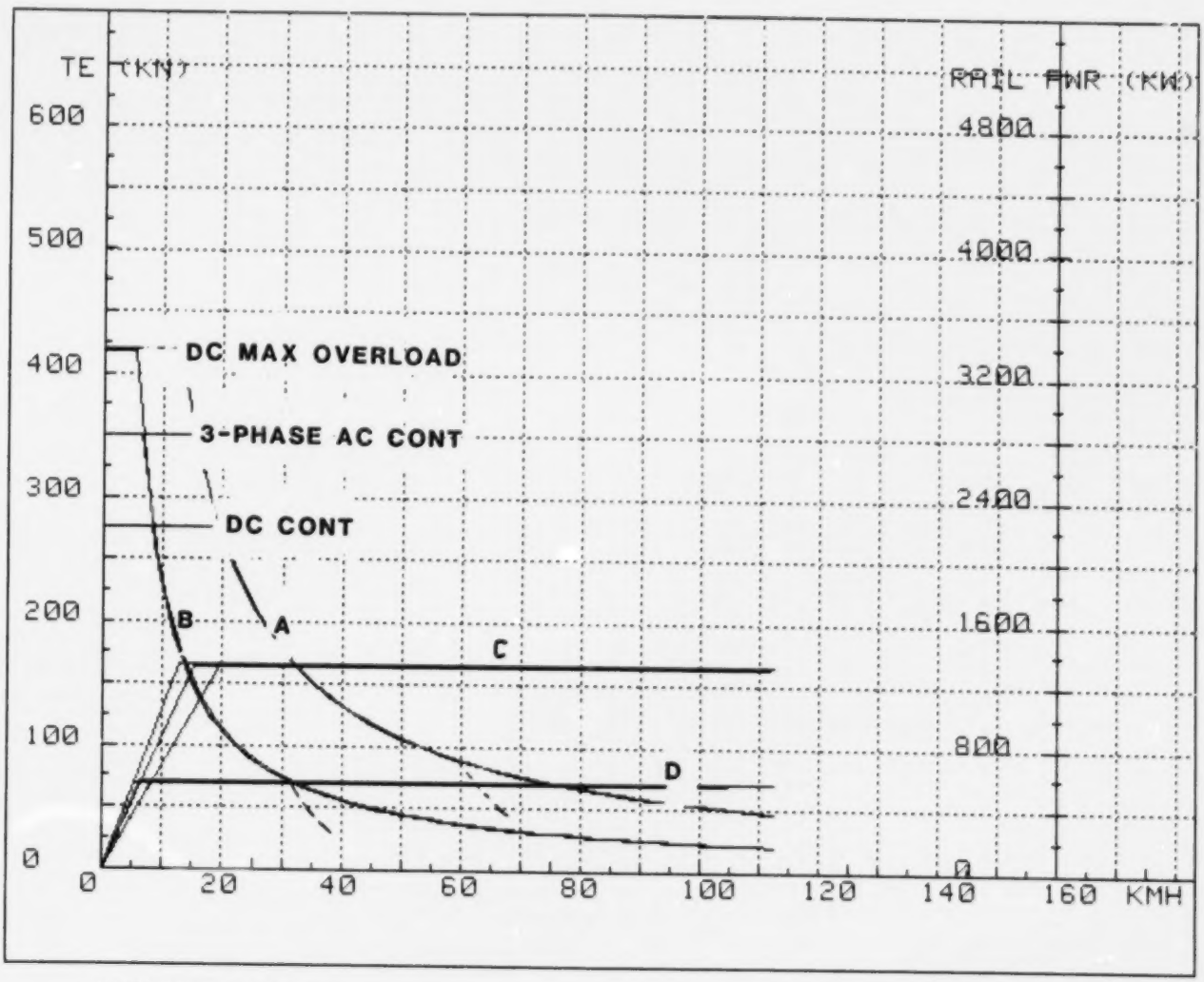
Arrangements using dedicated motors on each axle allow the operator considerable freedom in exchanging axles having wheels of different diameters. The control of individual axle slip must be taken care of by the control electronics. The motors may be either axle-hung or supported entirely in the truck, in which case appropriate couplings will be required. The historical development in North America has led to standardization on the arrangement using a dedicated transverse traction motor for each wheelset with axle mounting and nose suspension. Since motor failures are rare on shunter units there is no economic justification to provide a truck suspension for the motor on the basis of motor maintenance.

Figure 3 depicts the tractive effort/speed characteristic required from switcher locomotives equipped with engines of various power ratings. The power levels indicated in the characteristics refer to engine power destined for traction purposes and measured at the input of the alternator. The rail power will depend on the efficiency of the transmission system and will normally vary in the range of 80 to 90% of the alternator input power for traction. The transmission efficiency is important to the railways since, for a given rail performance it directly determines the loading of the engine and thus the fuel consumed. The curves in Figure 3 establish a requirement for a transmission efficiency of at least 88% for the switcher locomotive.

Two other important characteristics of the locomotive are discernable from Figure 3. The first of these is the tractive effort capability of the locomotive at start and low speed. At the indicated value of 274 KN (61,500 lb) of continuous tractive effort the adhesion utilization will vary in the range of 21 to 26% depending on the actual weight of the locomotive. Installing more continuous tractive effort capability than this is usually not reasonable since assignment of motive power for road switching is typically in this range in order to ensure a high reliability of completing train movements under all environmental conditions.

The characteristics show an overload tractive effort at low speed of about 50% above the continuous rating. This is desirable for special situations of a short term nature such as starting a train on a grade. The adhesion requirements associated with this tractive effort are very high and not always present in nature. To avoid overdimensioning the electrical equipment it has been normal practice that the continuous tractive effort is used as the design point and the equipment used in its overload capability where more tractive effort is required.

At the high speed end of the curves the locomotive may, depending on the type and sizing of transmission components, not be capable of utilizing full engine power. The tractive effort will fall off rapidly with speed in this area. This will not affect the capability of the locomotive to travel in a high-speed consist with other locomotives but will influence the amount of its tractive effort contribution.



CHARACTERISTICS

A: TE for 1791 KW (2400 HP) unit
B: TE for 746 KW (1000 HP) unit
C: Rail power for 1791 KW (2400 HP) unit
D: Rail power for 746 KW (1000 HP) unit

FIGURE 3

SWITCHER LOCOMOTIVE TRACTIVE EFFORT AND POWER CHARACTERISTICS

4.2.5.2 DC Motor

The DC series motor offers a good natural match to the locomotive diesel engine power characteristic. With relatively simple controls on the engine and alternator, the locomotive can be started and run at various speeds without overloading the diesel engine.

In the DC motor transmission system, the motors are connected directly to the rectifier output. Modern practice prefers parallel connection of all motors and avoidance of field weakening, since the power contactors and controls associated with the contactors are considered a prime failure source. Parallel-connected series DC motors share load adequately even with large wheel diameter differences and are reasonably stable under slippery rail condition.

DC traction motors draw large currents at locomotive start and the parallel connection of the motors requires that the alternator handle an appropriate multiple of this current. Since the tractive effort of the switcher at start is similar to that obtainable from a high-power road switcher this typically requires use of some of the same traction components. Figure 4 shows the continuous current limits for various CGE components. The alternator ratings are on a per-motor basis for a 4-axle locomotive with parallel motor connection. With the typical 83/20 gearing, it can be seen that only the GTA-17 traction alternator and (four each) type 752 traction motors can meet the required performance. The same motors are applicable to locomotives operating at 3,600 HP and are consequently considerably under-utilized in a switcher application in terms of power handled.

It would be possible to utilize lower rated components (the 761 motor and GTA-19 alternator, for example) if a higher reduction gear ratio could be applied. The allowable maximum speed of the motor of 3100 rpm would, however, limit the maximum speed of the locomotive to about 60 km/h. The locomotive could not be allowed in high speed consists without danger of destroying the motors.

It is very likely that the equipment complement of a Bombardier switcher locomotive using DC traction motors would continue to consist of type 752 traction motors mounted in the standard arrangement and supplied from a type GTA-17 alternator.

4.2.5.3 3-Phase AC induction Motor

The Type 6 FRA-4073 3-phase AC induction motor has recently been developed by BBC for use on North American diesel-electric road locomotives. This motor is rated at 746 kW/axle (1000 HP/axle) traction power into the alternator. The motor has been designed for installation

MOTOR	CONT. CURRENT	ENG. PWR. FOR TRACT
761	665	450
785	1195	650
752 PC	1195	650
752 AF	1270	500

WHEEL DIA. : 1016 mm (40 in)
GEAR RATIO : 83 / 20

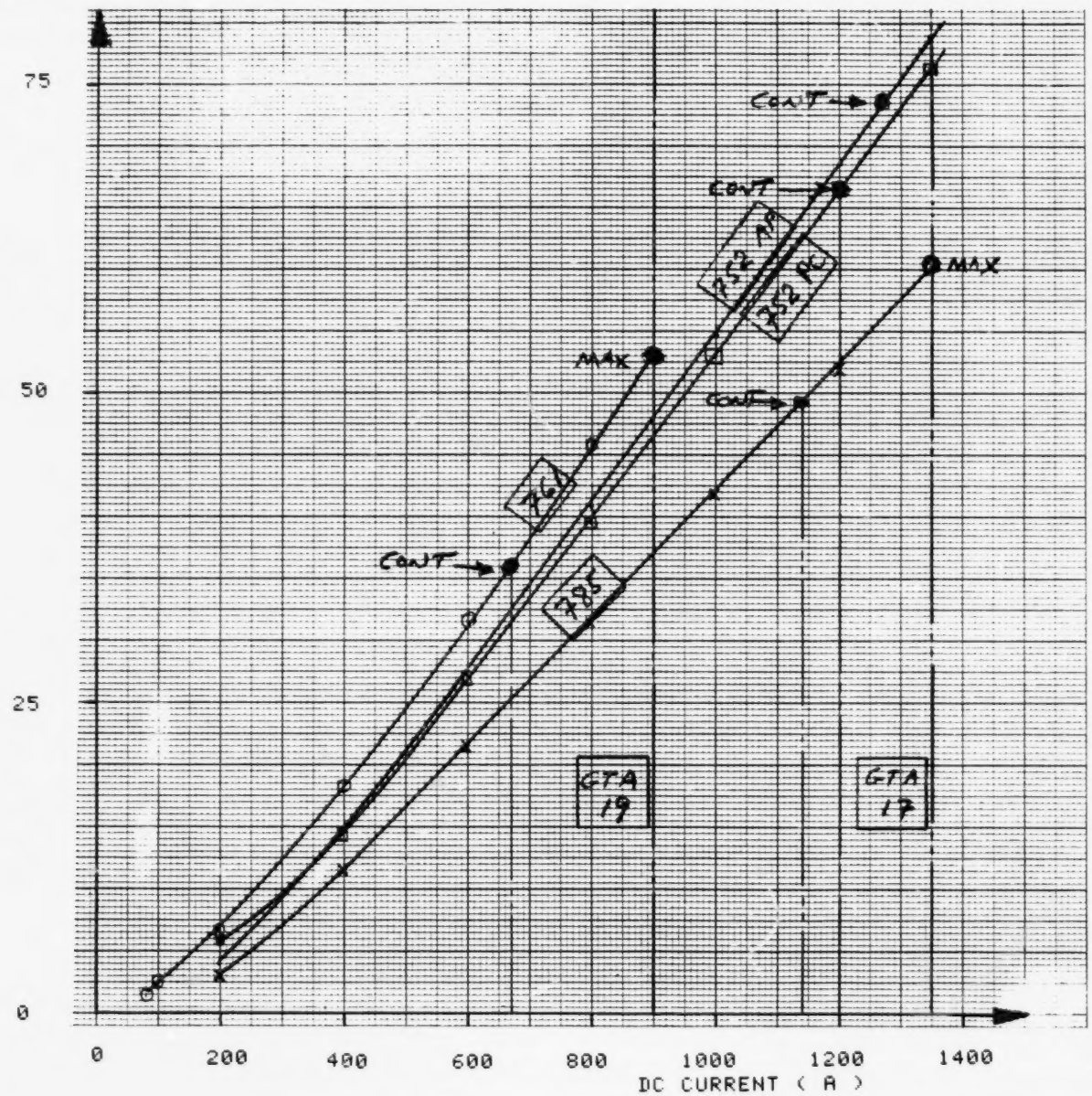


FIGURE 4

DC TRACTION MOTOR AND ALTERNATOR CAPABILITIES

into Bombardier trucks and, when used with a single reduction gearbox of 79/16 ratio, will provide a continuous starting effort of 350 kN (78,652 lb) for a locomotive with 4 driven axles. As can be seen from Figure 3 this would be approximately 27% above the continuous tractive effort available from 4 Type 752 DC traction motors using 83/20 gearing.

Unlike the DC traction system, little or no overload capability is usually available with 3-phase AC traction systems since the inverters have negligible overload capacity and installing a higher than necessary continuous capability in the inverter group would have serious system cost, weight and volume impacts.

The 27% higher continuous tractive capability of the 3-phase AC system over the existing DC system partially compensates the latter's advantage in overload capability for dealing with extreme traction situations.

In 3-phase AC traction systems designed for bussed connection of the traction motors, a semi-rigid electrical torsional coupling exists between all the axles which act to inhibit gross single axle slip while allowing sufficient slip (approx. 1%) for scrubbing of the rail surface by the leading wheels. This ensures that the existing adhesion conditions can be exploited to a maximum and often improved. The improved adhesion utilization correlates with an equipment design rated to handle the resulting higher tractive efforts. Locomotives equipped with 3-phase AC traction will consequently substantially outperform locomotives equipped with conventional DC traction when operating with heavy trains on severe grades at low speeds. This advantage is most pronounced for high power locomotives where the constant torque region extends to 20 or 30 km/hr. The switcher locomotive is, however, already power-limited at about 12 km/h and will only benefit significantly from 3-phase AC traction in terms of tractive capability if engaged in substantial hump service. For the same reason there would be little incentive for additional measures such as individual axle control or ground speed reference with this type of locomotive in order to improve adhesion utilization above that obtainable with the bussed motor connections.

The adoption of 3-phase AC traction on North American switcher locomotives will only occur if the required equipment is cost-competitive with existing DC propulsion. The most expensive element of any 3-phase AC traction system is the inverter group; reductions in installed inverter group capacity will act to lower system costs significantly.

The 6-FRA-4073 traction motor requires about 670 A in each phase with its present winding arrangement in order to generate its specified torque. The current can be reduced to between one-half and one-third by

using the same motor frame with an altered winding. This means the number and/or size of voltage-source inverters required can be reduced proportionate to the engine power capability.

The rewound motor with a minimum inverter solution will, however, generate a problem in regard to the high speed performance of the locomotive. As can be seen by referring to Figure 3 the tractive effort falls off with the inverse square function at speeds greater than approximately 30 to 60 km/h depending on the engine power rating. This is because, with the altered winding, full voltage at the motor will be reached at the relatively low speed of approximately 7 to 15 km/h. This speed, when multiplied by the field - weakening factor applicable to the motor of 4.0 gives the speed past which slip control of the motor reaches its limit and the motor characteristic will begin to be followed. Potential customers must be cognisant and accepting of this possible performance shortcoming or, alternately, a compromise winding must be selected for the motor with some degree of additional capacity provided in the locomotive electrical components.

The next important consideration in improving the competitive situation for 3-phase AC traction on switcher locomotives would be the traction motor itself. This will not be achieved by virtue of claimed maintenance and reliability advantages of the 3-phase AC motor over its DC counterpart; these are simply not significant in a switcher application where power levels and utilization are low and historically few DC motor failures occur.

The 6 FRA-4073 motor is basically a relatively low speed machine (3173 rpm max.) and is almost as large, heavy and costly as the 752 DC motor. For switcher applications it would be more reasonable to develop a new 3-phase AC traction motor - smaller, lighter, and less expensive than the 6 FRA-4073 - designed for high speed and for use with a two-stage gear reduction. A conceptual truck layout involving this motor is shown in Figure 5.

A trade-off will continue to exist for the new motor between high-speed performance and inverter current requirements in terms of the winding selected. The determination of the appropriate gear reduction, motor frame size, and winding would be the object of a vendor study in the event that a decision is reached to design and build a switcher equipped with 3-phase AC traction.

The 3-phase AC traction system for a North American switcher locomotive can be configured as either voltage - source or current-source, although the former has a great lead in the number of units actually used in locomotives worldwide. Conceptual block diagrams are depicted in Figure 6 for both systems. The decision on which system to employ

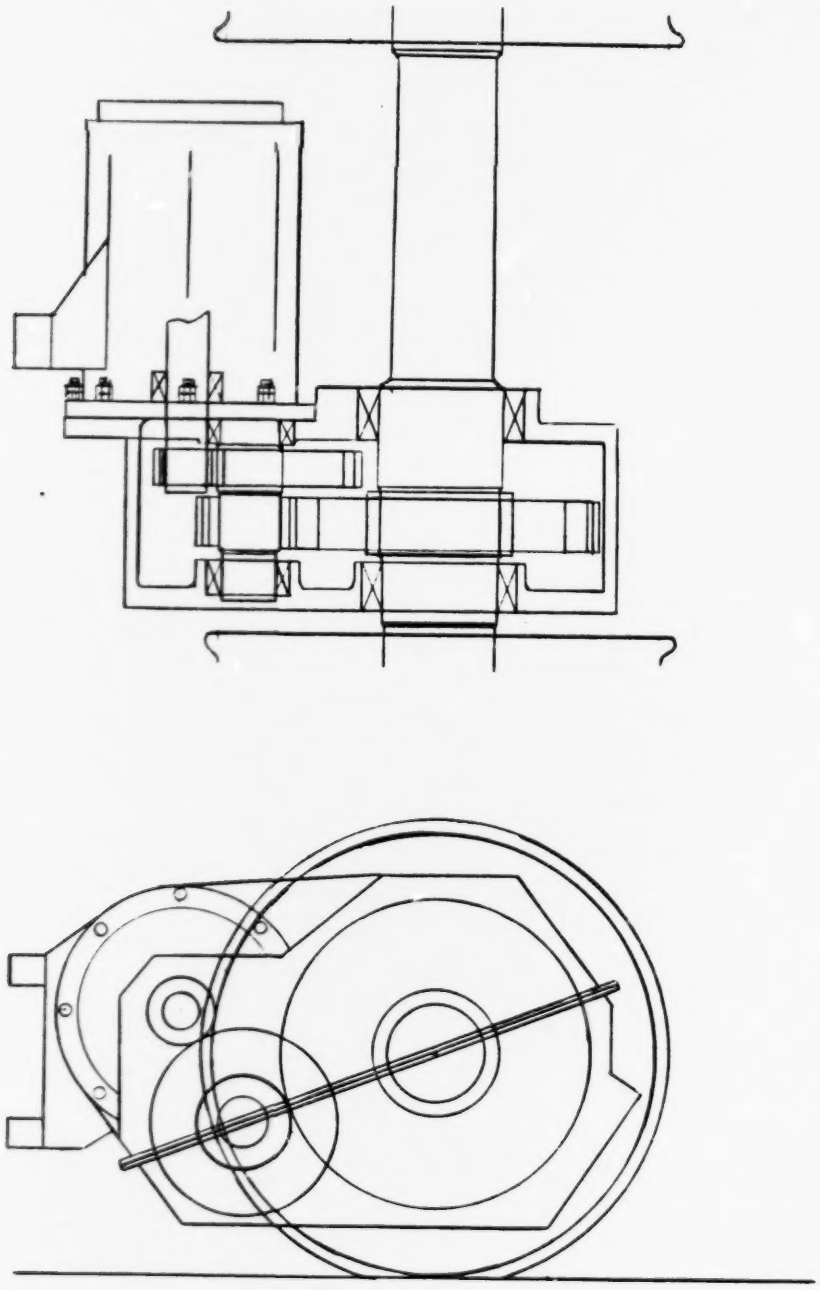
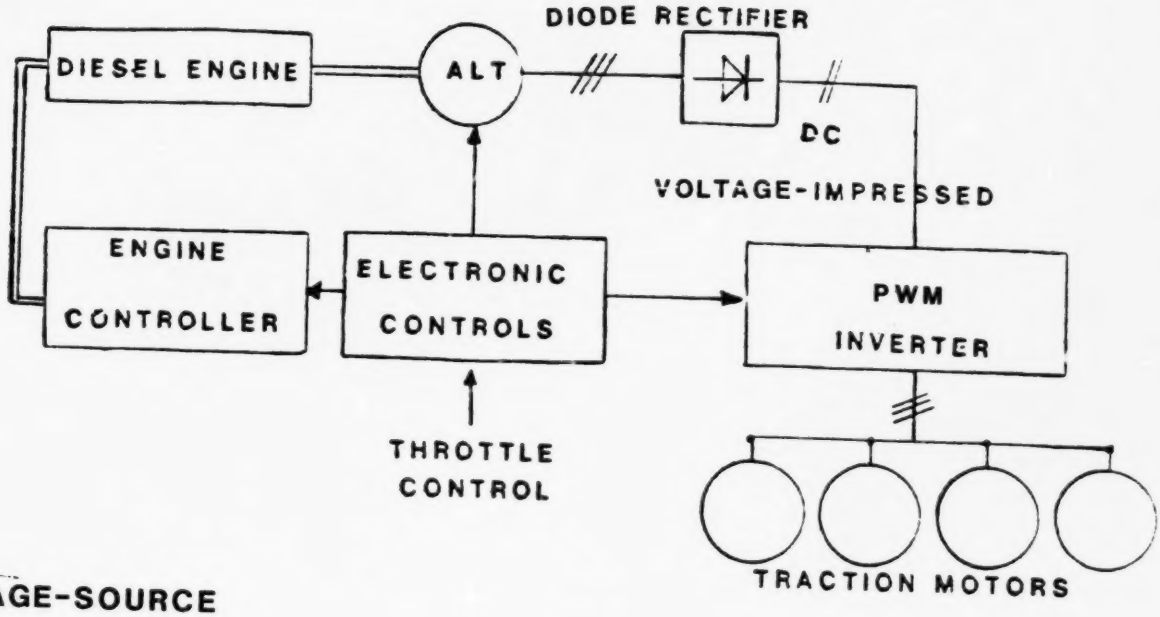
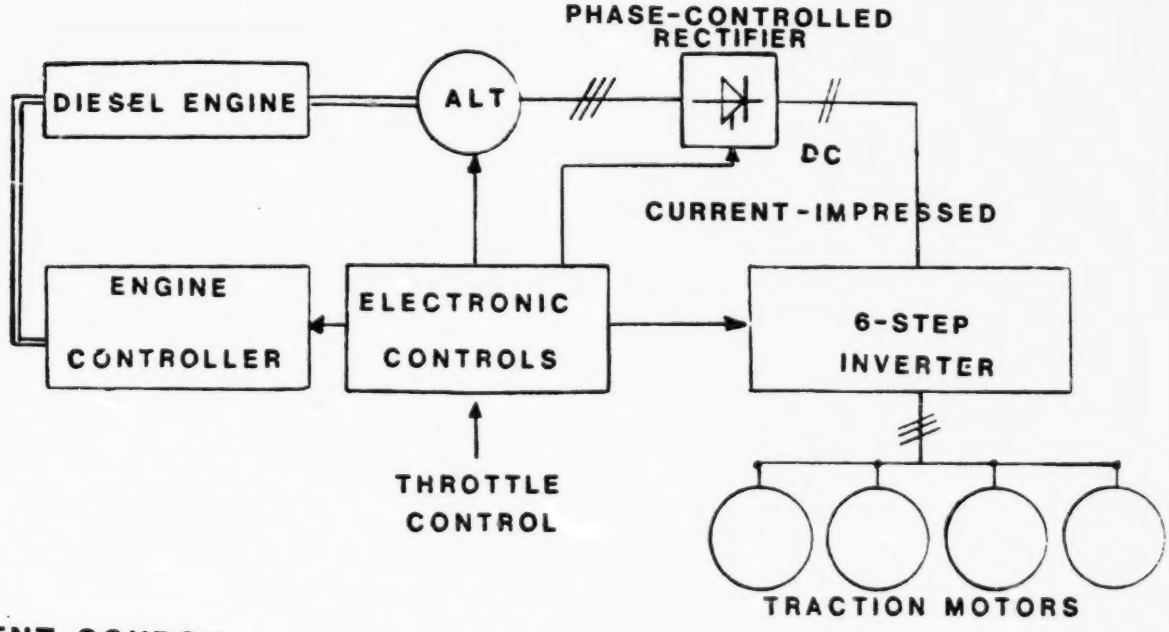


FIGURE 5

LAYOUT WITH HIGH-SPEED 3-PHASE AC MOTOR

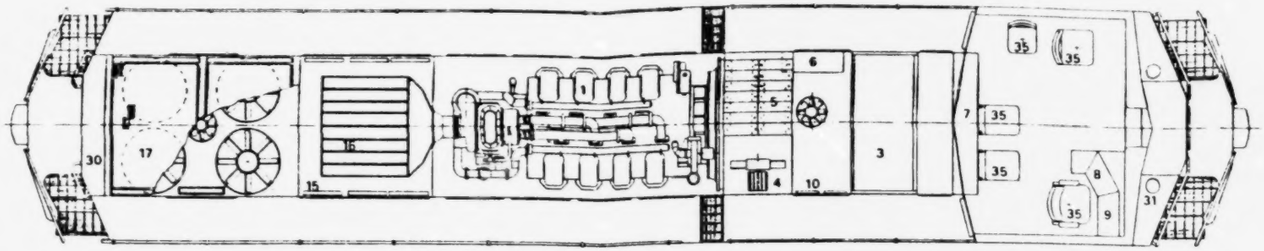


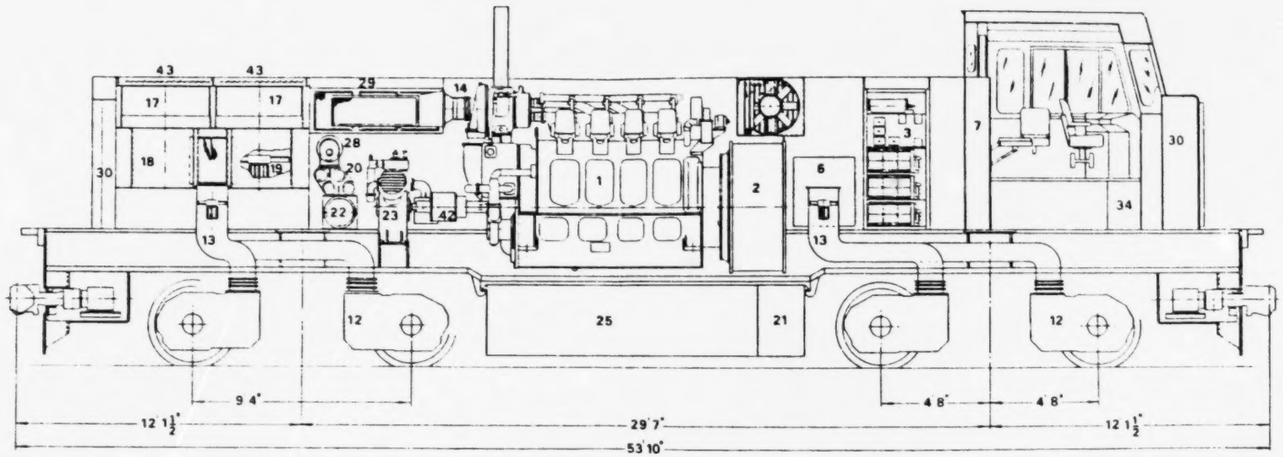
VOLTAGE-SOURCE

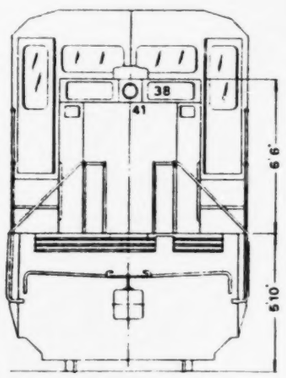


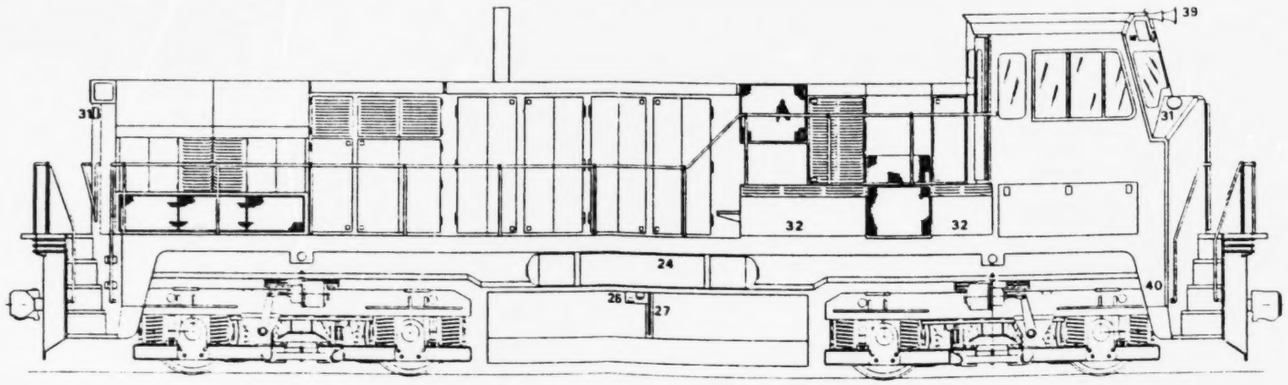
CURRENT-SOURCE

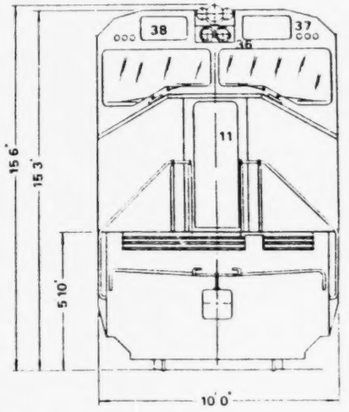
FIG. 6
3-PHASE AC TRACTION SYSTEMS











1 ENGINE
2 ALTERNATOR
3 INVERTERS
4 DYNAMIC BRAKE BLOWER
5 DYNAMIC BRAKE GRIDS
6 RECTIFIER
7 CONTROL COMPARTMENT
8 CONTROL DESK
9 BRAKE VALVES
10 CARBODY FILTER
11 SERVICE & EMERGENCY EXIT
12 TRACTION MOTOR
13 BLOWER TRACTION MOTOR
14 TURBOCHARGER
15 ENGINE AIR INTAKE PRIMARY
16 ENGINE AIR INTAKE SECONDARY
17 RADIATOR
18 RADIATOR FAN
19 RADIATOR FAN MOTOR
20 LUBRICATING OIL FILTER
21 ANTI POLLUTION TANK
22 LUBRICATING OIL COOLER
23 AIR COMPRESSOR
24 MAIN AIR RESERVOIR
25 FUEL TANK
26 FUEL FILLING CONNECTION
27 FUEL TANK GAUGE
28 FUEL OIL FILTER
29 ENGINE WATER EXPANS'N TANK
30 SAND BOX
31 SAND BOX FILL
32 BATTERIES
33 HAND BRAKE
34 CAB HEATER
35 CAB SEAT
36 HEADLIGHT
37 CLASSIFICATION LIGHT
38 BUMPER BOX
39 HORN
40 BELL
41 BACK UP LIGHT
42 CLUTCH COMPRESSOR
43 SHUTTERS

FIG. 7

Bombardier Inc
Bombardier Inc
Rail and Diesel Products Division
Montreal Canada

GENERAL ARRG'T

MSK 0 5877

AO

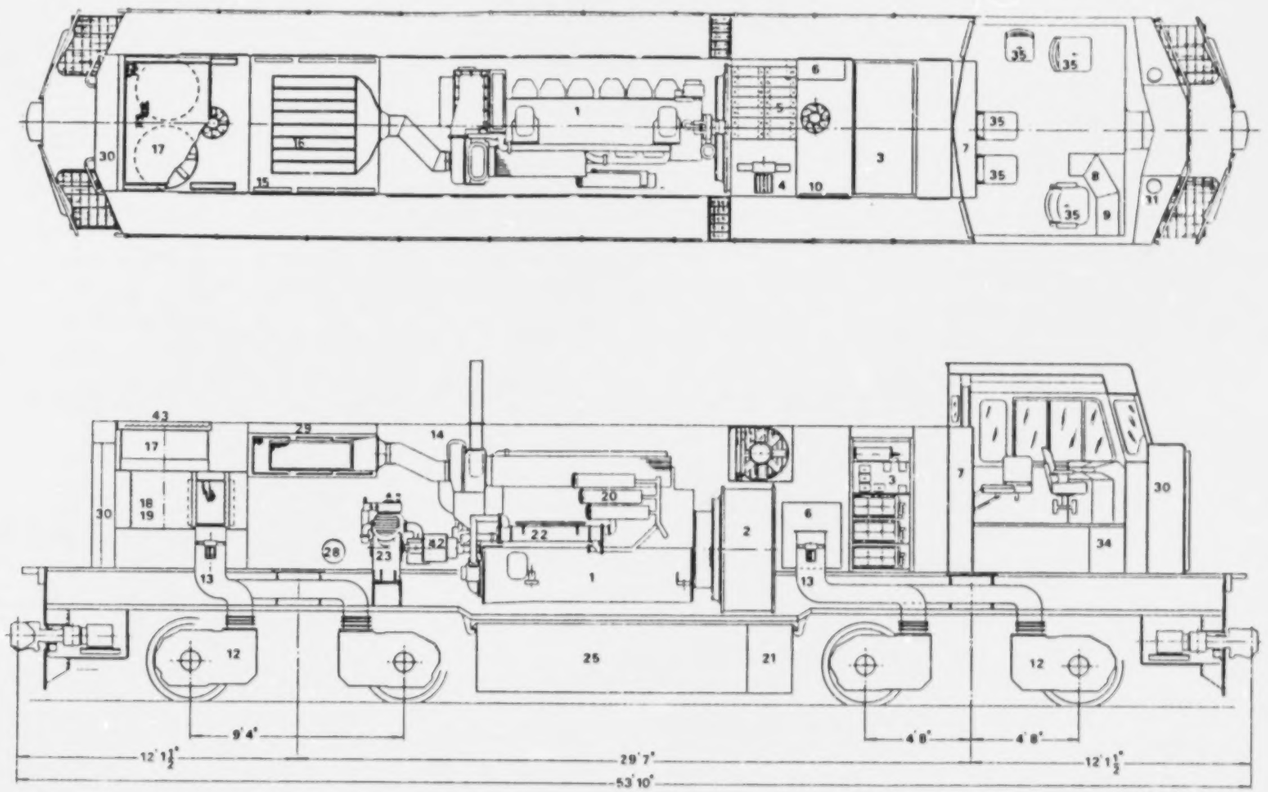


FIG. 8

GENERAL ARRGT

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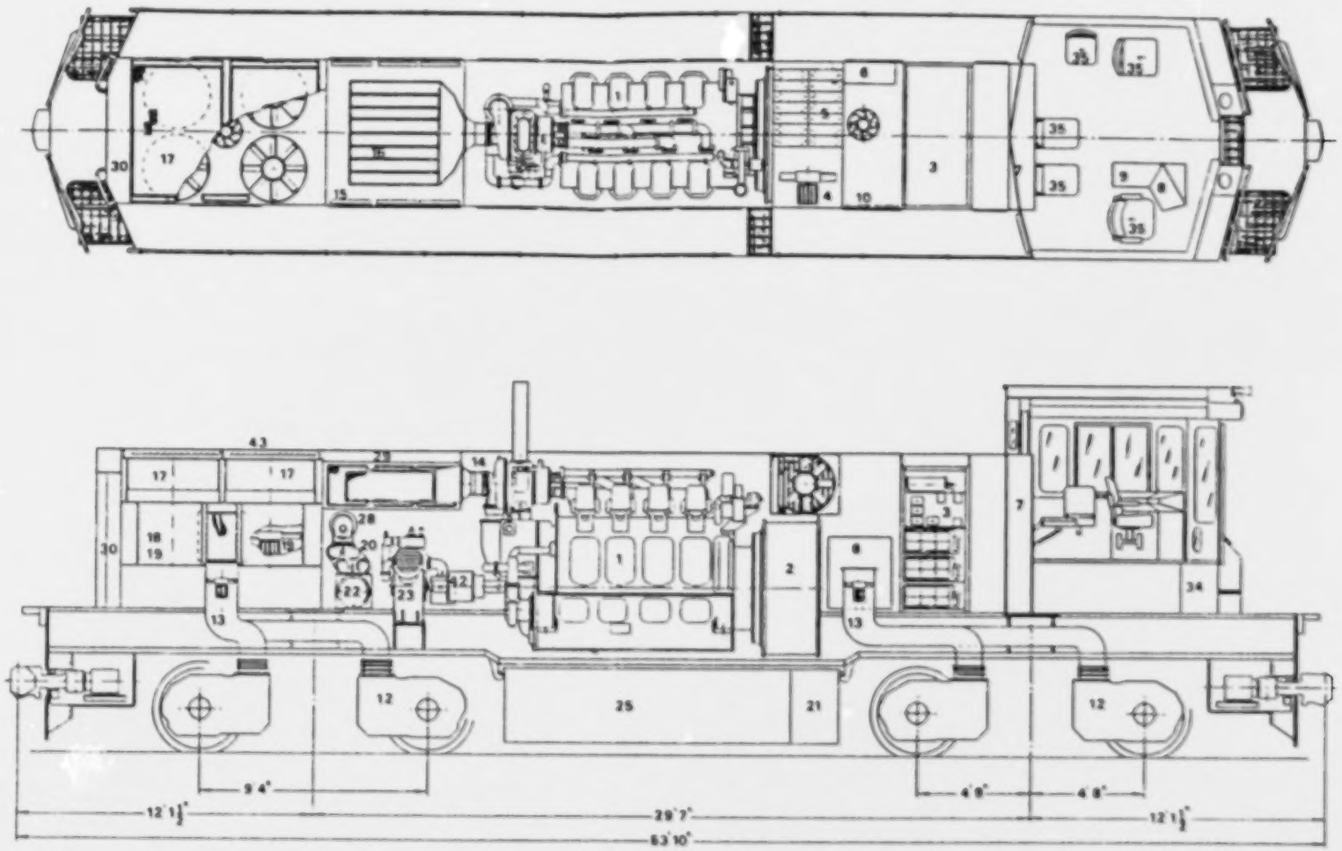
1 ENGINE
2 ALTERNATOR
3 INVERTERS
4 DYNAMIC BRAKE BLOWER
5 DYNAMIC BRAKE GRIDS
6 RECTIFIER
7 CONTROL COMPARTMENT
8 CONTROL DESK
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13 BLOWER - TRACTION MOTOR
14 TURBOCHARGER
15 ENGINE AIR INTAKE - PRIMARY
16 ENGINE AIR INTAKE - SECONDARY
17 RADIATOR
18 RADIATOR FAN
19 RADIATOR FAN MOTOR
20 LUBRICATING OIL FILTER
21 ANTI-POLLUTION TANK
22 LUBRICATING OIL COOLER
23 AIR COMPRESSOR
24 MAIN AIR RESERVOIR
25 FUEL TANK
29 FUEL FILLING CONNECTION
27 FUEL TANK GAUGE
28 FUEL OIL FILTER
29 ENGINE WATER EXPANS'N TANK
30 SAND BOX
31 SAND BOX FILL
32 BATTERIES
33 HAND BRAKE
34 CAB HEATER
35 CAB SEAT
36 HEADLIGHT
37 CLASSIFICATION LIGHT
38 NUMBER BOX
39 HORN
40 BELL
41 BACK-UP LIGHT
42 CLUTCH COMPRESSOR
43 SHUTTERS
12'1½"
9'4"
29'7"
83'10"
4'8"
4'8"
12'1½"
15'6"
15'3"
5'10"
10'0"
6'6"
5'10"

FIG. 9

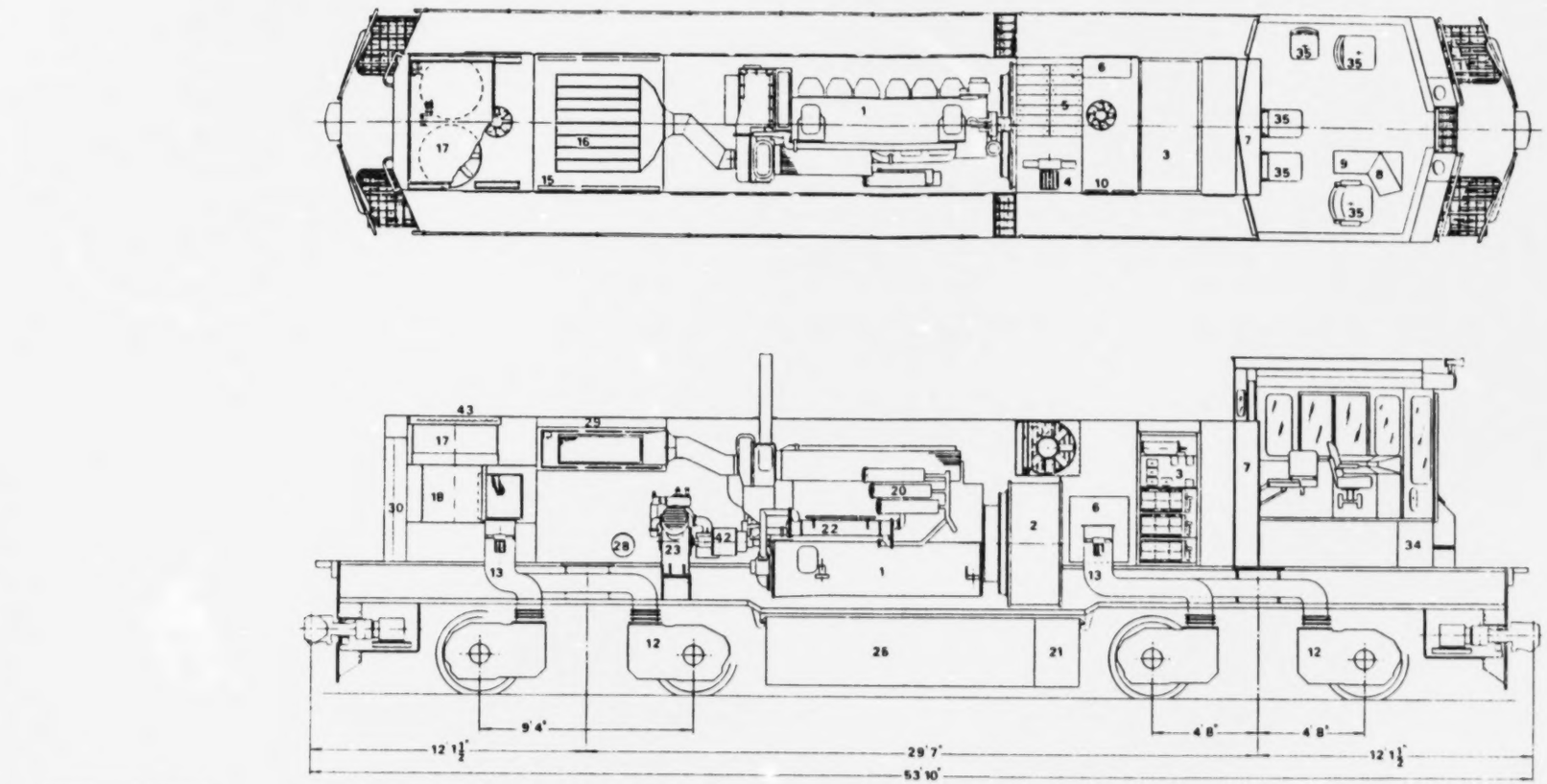


FIG. 10

Bombardier Inc
GENERAL ARRG T
MSK D 5880

will depend on analysis of vendor proposals which may be expected in the event of a go-ahead on the preliminary design of a 3-phase AC Bombardier switcher locomotive.

To facilitate the study of equipment installation a current-source system as developed by Siemens was assumed and resulted in the layout shown in Figures 7 through 10. The layouts are discussed in detail in Section 5 of this report.

The basic reason for selection of the Siemens system was the availability of power conversion equipment utilizing boiling freon cooling as opposed to direct air cooling typical with present BBC equipment. The freon system is considered to be less sensitive to the environment and to be more compact.

4.3 Prime Mover

Selection of an engine for a given locomotive application is one of the more critical factors which determine whether a particular locomotive model will experience success or failure. The bulk of normal locomotive service and maintenance activity is invariably centered on the engine as is replacement parts consumption. The North American medium speed diesel engine, designed specifically for railroad service, has evolved into a rugged machine capable of reliable performance under adverse conditions in the efficient conversion of diesel fuel to mechanical energy.

Builders of switchers in the lower horsepower ranges have used higher-speed smaller-bore engines to considerable advantage over many years. These quick-running engines produce more power per unit weight, are smaller, thus offering more flexibility in chassis arrangement, and provide the user with the same advantages that off-road vehicle and construction equipment operators enjoy - i.e. easy shut-down, quick start-up, fast acceleration, anti-freeze protection, etc. The manufacturers of this type of engine have also participated in the horsepower race by increasing power output per cylinder, and, if the maximum power of a single engine is insufficient, the builders will offer two engine sets on a single chassis in satisfaction of a customer's motive power requirements.

Notwithstanding the above, most railroads that were interviewed stated unequivically that it would be disadvantageous, in their opinion, to maintain a locomotive fleet comprising a variety of both high-speed and medium-speed diesel engines. Furthermore, the higher-speed engines

can and often do experience higher mortality rates of the major wearing parts due primarily to higher rubbing speeds, and in some instances, differing maintenance and repair procedures than those required for medium-speed engines. High-speed engines have also proven to be less fuel efficient than medium-speed engines regardless of the duty cycle to which they are subjected. It is therefore economically advantageous for the railroads to avoid any intrusion of quick-running engines in their motive power fleets.

The Bombardier Model 251 medium-speed diesel engine is manufactured in Canada, the United States, and under license overseas. It has become one of the accepted railroad "standard" engines in North America and is currently in its ultimate development stage wherein it will be offered for reliable performance at 187 kW (250 HP)/cylinder, a 10% increase over previous maximum allowable horsepower ratings. The 6 cylinder in-line and the V-8 versions of this engine would then be adequate for the 740 kW (1000 HP) to 1492 kW (2000 HP) range of power requirements identified for switcher/transfer service but this would then be at the upper design limit for reliable performance of the Model 251 engine. The V-12 version could satisfy the upper range to 1791 kW (2400 HP) but its use would not be economical from the standpoint of initial cost and allocation of space.

Bombardier is currently in the initial hardware stage of developing a new engine with all of the salient features of the model 251, but designed for a range of 205 kW (275 HP) to 238 kW (320 HP) per cylinder. The V-8 version of this new engine, designated the B2400, will be substituted for the V-12 version of the 251 engine, where applicable.

The performance criteria for diesel engines used in switcher service in flat yards versus those used in heavy-duty transfer service or in mainline MU consists differs substantially. The following tabulation represents the standard AAR duty cycle for each type of service and gives the average percentage of time that a locomotive spends in each of the engine notch settings.

Notch	Heavy	Medium	Light	Switcher
8	30	17	9	1
7	3	4	3	0.5
6	3	4	3	0.5
5	3	4	3	1
4	3	4	3	2
3	3	4	3	4
2	3	4	3	7
1	3	4	3	7
HI idle	13.7	15.3	22.0	25.7
Low idle	27.3	30.7	44.0	51.3
DB	8	9	4	0
	100%	100%	100%	100%

TABLE 12

AAR DUTY CYCLE BY TYPE OF SERVICE

It will be noted that idling (not working) represents the largest portion of each duty cycle - from 41% for heavy duty to 77% for switcher service. It should also be noticed that all except the switcher duty cycle show a uniform percentage from Notch 1 thru Notch 7 with a proportionately larger percentage of time spent in Notch 8 (maximum engine speed). The switcher duty cycle, with greater activity in the lower and medium notch positions, places more stringent acceleration requirements on the diesel engine when operating in flat yard service. This has traditionally precipitated a problem with medium speed turbocharged diesels equipped with conventional exhaust gas driven turbochargers because of the inability of the large rotating mass of the turborotor to respond quickly to the demands made upon it for more charge air as the engine begins to accelerate.

It is proposed that the adoption of two small turbochargers with smaller rotors and a much smaller aggregate mass, plus a variable electronic device for reducing load while the engine is picking up speed, will provide the required acceleration characteristics for yard switcher service without compromising medium speed engine performance in heavier duty transfer service. Other devices such as mechanically driven roots-type blowers, air-jet assists, and turbo bypass overspeed protection were considered but preliminary investigations show them to be less effective than the use of the two smaller turbochargers.

4.4 Cooling System

4.4.1 Air

Directly-coupled engine-driven blowers are standard on many conventional switching and transfer locomotives. The four traction motors are often supplied by a single blower unit. The air enters a plenum chamber in the frame and ultimately finds its way to each traction motor. This makes an unbalanced, inefficient arrangement whereby the air supply is a function of the engine speed. Some of the blower air is also diverted and utilized to pressurize the contactor compartment. During cold weather when traction motors require less cooling, a surplus of air is supplied by the blower with this arrangement resulting in an unnecessarily high parasitic load demand on the diesel engine.

According to the concept developed for the new switching locomotive three independent blowers are proposed for cooling the electrical equipment. Each truck, containing two motors, has its own blower and filters. The third system supplies the rectifier and pressurizes the contactor compartment. Continuous monitoring of temperature in the equipment and drive of the blowers by means of 3-phase AC motors is used in order to optimize operation of blowers independent of each other. Depending on the pressure to volume requirement for the traction motors, axial ducted fans may be applied. The air is drawn through panel filters and led to the motors in properly designed, separate ducts. With this system losses are kept to a minimum.

The alternator is self-ventilated and does not require a separate blower. It is supplied with filtered air from carbody filters. The discharge sweeps the engine to slightly pressurize the engine compartment and prevent dust from entering.

4.4.2 Water

A gear-driven centrifugal pump integral with the diesel engine circulates cooling water through the engine, turbocharger, charge air aftercoolers, radiators and the compressor. A slightly pressurized expansion tank is provided to maintain a minimum water level and protect the turbocharger when shutting down the engine. Abnormally low water level in the expansion tank actuates a switch and shuts down the engine.

Significant improvements have been made to diesel engine cooling systems in recent years. They have come about due to the increased emphasis placed on reduced fuel consumption. Introduction of a radiator by-pass system can provide cooler water to the turbocharger aftercooler. This results in a significant improvement of the engine specific fuel consumption, a lower air temperature at the engine intake manifold and a lower exhaust temperature which helps to prolong the life of engine components.

Figure 11 shows a representative flow diagram of the existing system. The total engine water flow circulates through the radiators and the temperature drop through the radiator would be typically 8.3°C (15°F).

Figure 12 shows the water flow diagram of the proposed radiator by-pass system. Only one third of the engine flow passes through the radiators. Temperature drop through the radiators is estimated to be approximately 25°C (45°F).

The heat rejection capacity of the radiators in the proposed system has been maintained. This means that the average water temperature through the radiator is approximately the same as on the existing cooling system and therefore, the radiator fan horsepower remains the same. The net result is 11°C (20°F) cooler water to the aftercooler providing an overall engine specific fuel consumption improvement. An added component, an inducer, is used to help draw the water through the much higher impendance of the radiator and equipment to be cooled.

Radiators manufactured today are designed to have a minimum life expectancy of fifteen years. Scale from the engine is serious enough to justify installation of a water strainer upstream of the radiators for protection. These strainers are designed for a minimum maintenance period of ninety-two days and are easy to remove. Removing radiators for replacement or cleaning withholds the locomotive from service and is therefore very expensive in terms of maintenance costs and loss of operating time.

The radiators in an overhead configuration dissipate 60% of the heat input from the engine. During cold weather, the engine is required to idle at faster speed in order to input sufficient energy into the water to prevent freeze-ups in the system. Running the engine at any speed other than idle increases fuel consumption, and hence is undesirable. A system may, however, be implemented in which the radiators are drained and by-passed as soon as the engine water outlet temperature falls below a predetermined level. An encouraging preliminary study has been completed at Bombardier Inc. to analyze the feasibility of this system. Since in the standby mode during overnight storage of a locomotive 80% of the energy supplied by a standby heater would be lost through the radiators, the radiator by-pass system could result in a power savings exceeding 65 kW in yard stand-by power for each locomotive so equipped.

4.5 Carbody Construction

The individual hoods and compartments have been planned as modular units, envisioning interchangeability and serviceability. The hoods, underframe and cab have been designed to simplify engineering and

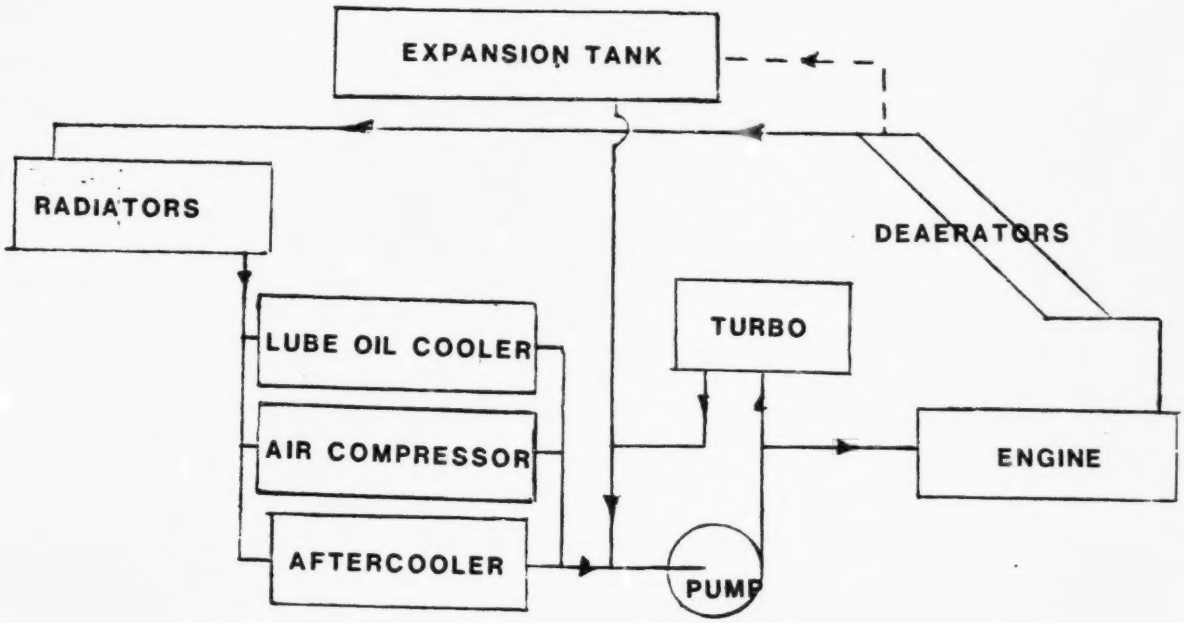


FIGURE 11

EXISTING COOLING SYSTEM

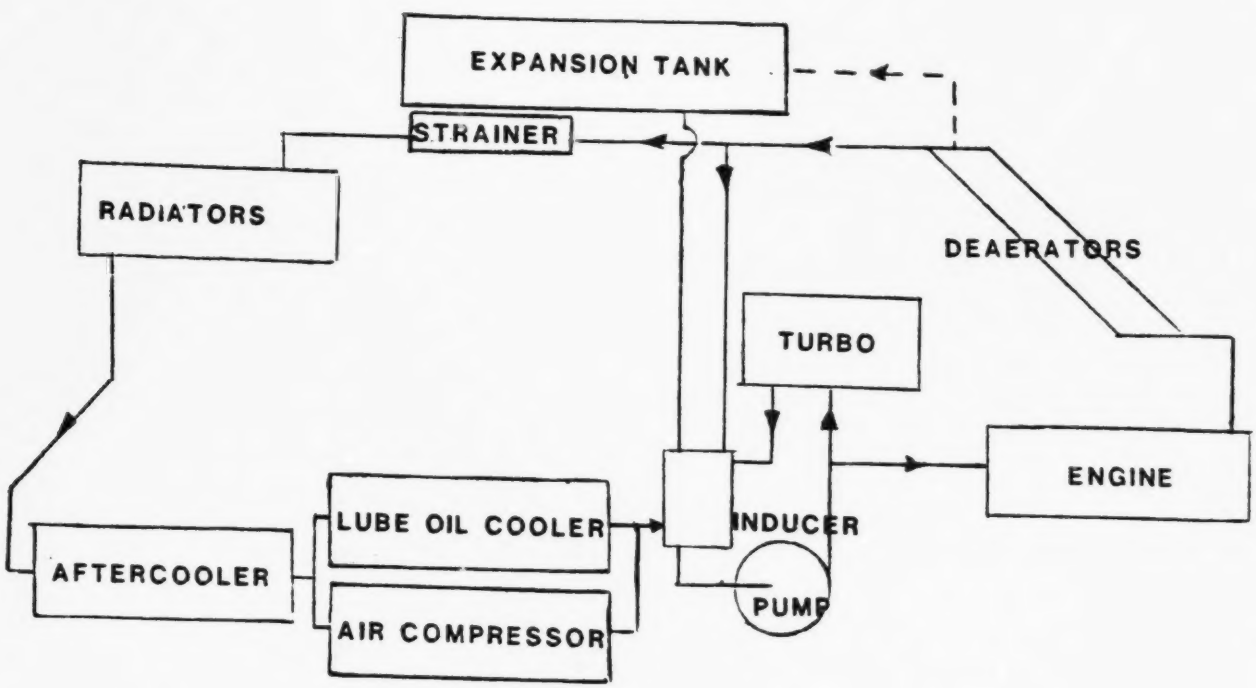


FIGURE 12

RADIATOR BYPASS COOLING SYSTEM

standardize manufacturing. They are of welded steel construction and are removable unless otherwise mentioned. Electrical junctions are made using suitable disconnects which allow for quick and easy removal without having to disconnect individual wires. To allow versatility in the product with regard to customer options, various additional or alternative equipment may be adapted in the space provided.

The cab structure is welded to the underfloor and contains a raised floor. Insulation is applied on the inside of the cab to effectively shield against heat losses and sound penetration. The front wall is reinforced and designed for operator protection in case of a collision. Improved visibility, particularly of the four corner steps, has been achieved by the raised cab floor in conjunction with low profile hoods and, in a switcher version, large window areas. The interior is furnished with sound absorbing and abrasion resistant materials. Sufficient space has been provided to allow a maximum of five crew members to be seated. Cab options such as a refrigerator, hot plate and watercooler can be provided.

If a short hood is applied, as is usually desired for transfer service, it is designed to provide collision protection. In this case the overall window area will be reduced somewhat.

The contactor compartment contains the control equipment including microprocessors for propulsion and auxiliary equipment control. These controls are packaged on easy-to-remove plug-in cards which are assembled on standard racks. The compartment, maintained under positive air pressure to keep out dirt and water, is welded to the underfloor and the cab. The cab rear wall contains the control switches for various locomotive functions such as heating, cooling, blowers, and lighting.

If 3-phase AC traction is used,a supplementary frame located behind the contactor compartment will contain the inverters, inductors and capacitors as well as a cooling fan. This unit is welded to the underfloor, since each component is removable individually. The auxiliary hood encloses this supplementary frame, lead truck traction motor blower, dynamic brake (if applied) and alternator.

The engine hood encloses the prime mover. Doors on each side allow easy access for simple maintenance and repair work. The entire upper portion is removable, including silencer, if required. Hatches in the roof provide access to the power assemblies. A detachable panel permits the removal of the complete turbocharger without having to dismantle the remainder of the roof.

The radiator hood provides space for up to three modules of which one or two will be cooling modules. Each cooling module supports a

radiator and its two cooling fans including the associated electric motor drives. A single radiator module will sufficiently cool an engine rated for traction up to 1007 kW (1350 HP). For higher power two units are required. The third module incorporates the water expansion tank and the filter housing for the engine air, welded together and removable as a unit. Doors on either side of this module permit easy access to the compressor as well as to the lube oil and fuel filter for routine maintenance. The compressor may be removed sideways, however, it must be raised first to clear the underfloor.

The underfloor is designed to accept a six or eight cylinder engine together with its flange-mounted alternator. The objective was to install the prime mover as low as possible to achieve a low center of gravity and realize a low-hood height. Moreover, the neutral axis of the main floor beams has been lowered to minimize the distance between the coupler height and the neutral axis of the beam. This will reduce the bending moment incurred due to tractive effort and buffing load, and hence minimize weight transfer between front and rear trucks. The beams are spaced apart in the center to accommodate the alternator and are closed in at the bolster to allow the application of the zero-weight-transfer truck, as well as the flex and steerable trucks.

Provision is made to supply a fuel tank of maximum 9100 liters (2000 imperial gallons), including a 450 liter (100 imperial gallon) pollution tank. The pollution tank is an integral part of the fuel tank and is designed to allow freezing of the contaminants without generating cracks. Provision has been made to clean the fuel tank and the pollution tank by installation of clean-out covers. A hot well is incorporated into the fuel tank of approximately 45 l (10 imp gal). Its purpose is to contain the hot fuel, returning from the engine, in the same pocket as the suction pipe (supply line to the engine), such that less than 50% of the fuel to the engine is made up from the tank. This always assures a warm fuel supply which results in reduced waxing in cold weather and also reduces the load on the fuel pump.

The tank is removable sideways without having to remove any major equipment supported by the underfloor.

4.6 Auxiliary Equipment

Engine power is used to drive a number of on-board locomotive loads in addition to the traction system. These auxiliary (or "parasitic") loads, while necessary for proper operation of the locomotive and to provide an acceptable level of crew comfort, use a significant portion of the engine's power. Auxiliary loads for a typical conventional locomotive are shown in Figure 13 top, expressed as a percentage of engine power. Effort must be directed toward reducing the auxiliary loads in order to reduce fuel consumption, and to do this with affordable and easily maintainable equipment.

The major on-board auxiliary loads are as follows:

- Alternator excitation
- Battery charging
- Heating, lighting, air conditioning, controls
- Fuel pump/crankcase exhauster
- Traction motor blower(s)
- Other electrical equipment blowers
- Air compressor
- Radiator cooling fan(s).

There are numerous possibilities for supplying power to these auxiliary loads on a switcher locomotive. Past Bombardier layouts for switcher locomotives have typically distributed auxiliary power as follows (Figure 14 top):

Baseline Concept

Mechanical Drive From Engine (1100 rpm)

- Air compressor direct-coupled to engine free end.

- Single radiator cooling fan through 3-step eddy-current clutch.

Mechanical Drive Through Step-up Gear (2300 rpm)

- Single blower for traction motors/rectifier/contactor compartment

DC Generators (75 VDC, 2300 rpm)

- Alternator excitation
- Fuel pump/crankcase exhauster
- Battery charging
- Heating, lighting, controls.

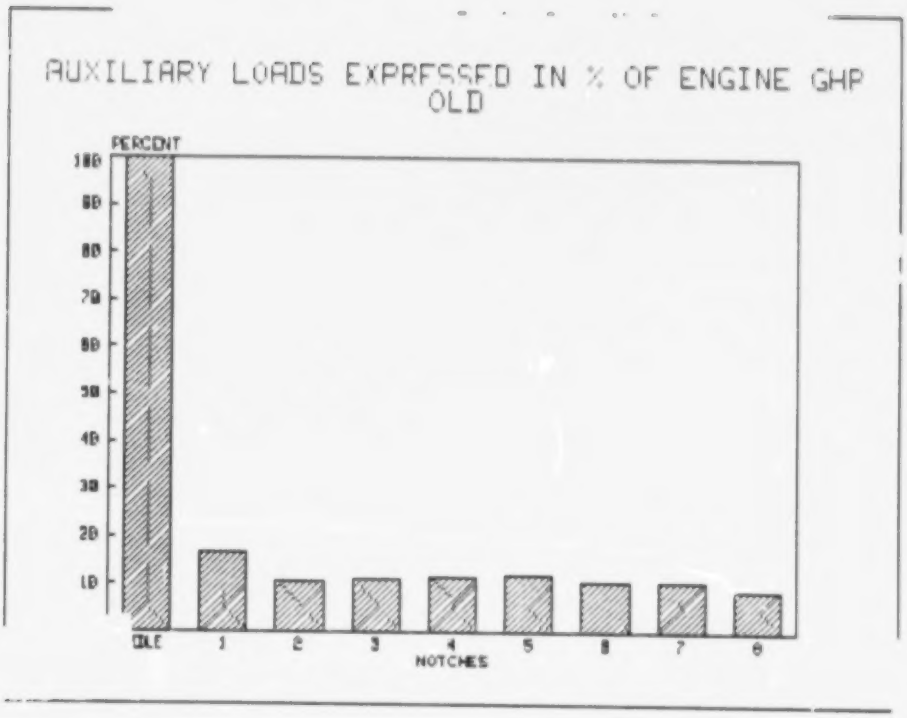
This is unquestionably the simplest and least expensive solution to providing auxiliary equipment drives. It does, however, suffer from the disadvantage of excessive energy consumption in the following areas:

- Blower dimensioned for supplying sufficient air under worst-case conditions will draw unnecessarily high power under normal conditions because its speed is tied to engine speed. Centralized position results in high duct losses.

- Air compressor draws significant power even when unloaded since it continues to rotate at engine speed.

- 3-step control of eddy-current clutch results in excessive power consumption in clutch/fan combination.

These three loads account for about 80% of the total auxiliary power requirements on the locomotive. The following summarizes concepts



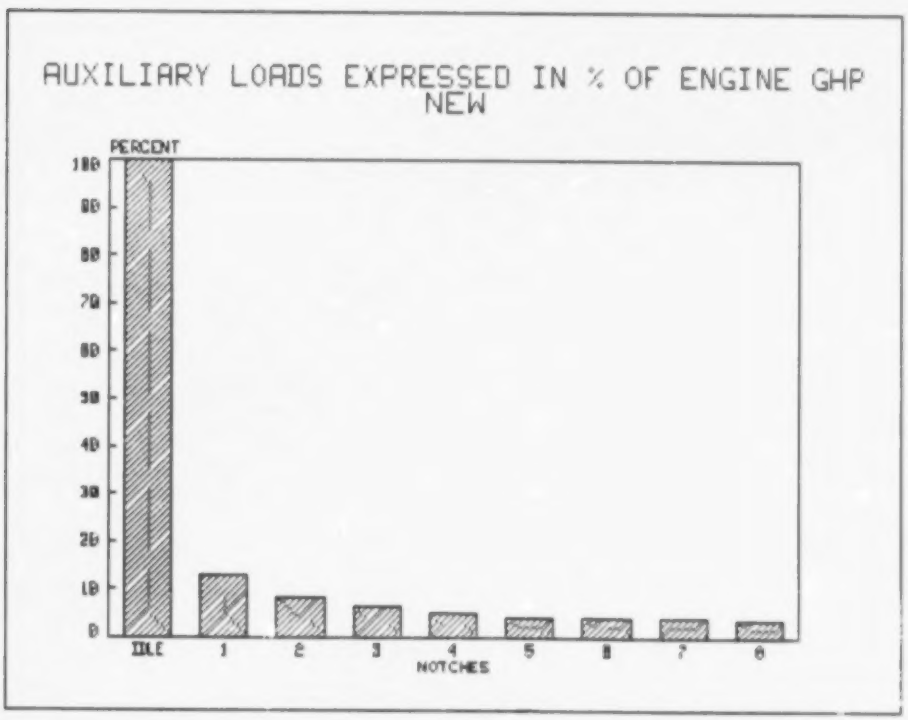


FIG 13

PARASITIC LOADS

that could be adopted for eliminating some or all of the above problems:

Concept 1 (Mechanical Modified Drive)

Mechanical Drive From Engine (1100 rpm)

- Air compressor direct coupled to engine (no improvement).

- Single radiator cooling fan through infinitely variable eddy-current clutch (improvement at some engine speeds).

Mechanical Drive Through Step-up Gear (2300 rpm)

- Single blower for traction motors/rectifier/contactor compartment with variable inlet vane control (some improvement in blower power draw at reduced air flows).

DC generators (75 VDC, 2300 rpm)

- Alternator excitation
- Battery charging
- Heating, lighting, controls
- Fuel pump/crankcase exhauster.

This concept allows resolution of some of the above-cited problems while maintaining the majority of the existing equipment. Low hood height will dictate side-mounted radiators for good radiator efficiency with the single large fan. The resulting hot air in this area of the locomotive will prohibit the installation of any other equipment there. The air compressor must have a through-shaft for transmitting power to the radiator fan without means of decoupling.

Concept 2 (Addition of Electrical Drives and Further Mechanical Drive Modifications)

Mechanical Drive From Engine (1100 rpm)

- Air compressor direct-coupled to engine through pneumatic clutch (compressor can be stopped).

Auxiliary Alternator (1100 rpm/675V/92Hz)

- Multiple radiator cooling fans with dual-speed 3-phase AC motor drives (power consumption minimized)
- Power converter (75 VDC)
- Auxiliary alternator excitation
- Battery charging

- Heating, lighting, controls
- Dedicated blowers for traction motors in each truck and inverters (if used) driven by dual speed 3-phase AC motors (power consumption minimized)
- Main alternator excitation.

This concept is depicted in Figure 14 bottom.

The electric fan drives allow the use of roof-mounted radiators thereby enabling an air intake and traction motor blower to be installed in the rear area of the locomotive. Duct losses are significantly reduced by the more direct ventilation arrangement and dual speed control of the traction motor blower motor enables power draw to be held to a minimum consistent with adequate cooling.

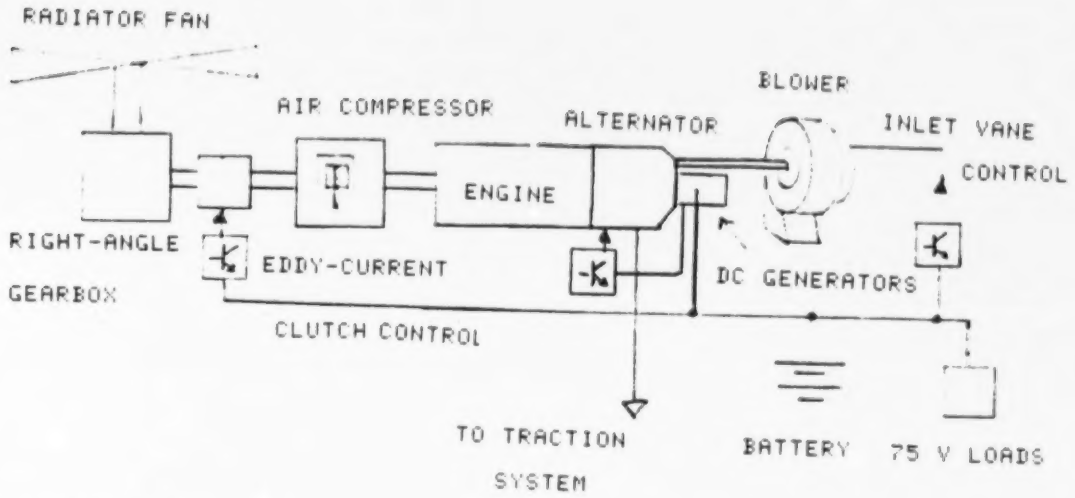
The compressor no longer requires a through-shaft and can therefore be equipped with a pneumatically-operated clutch on its input shaft.

The auxiliary alternator will be mounted on the main alternator shaft and be enclosed by the main alternator housing (tandem alternator). Since fan speed is coupled to engine speed via the auxiliary alternator frequency, the fan motors must be switchable in and out and between two speeds in order to obtain suitable radiator cooling, while keeping power requirements low. The same holds for the various blower drives. This is the system shown in the locomotive layouts in Figures 7 through 10.

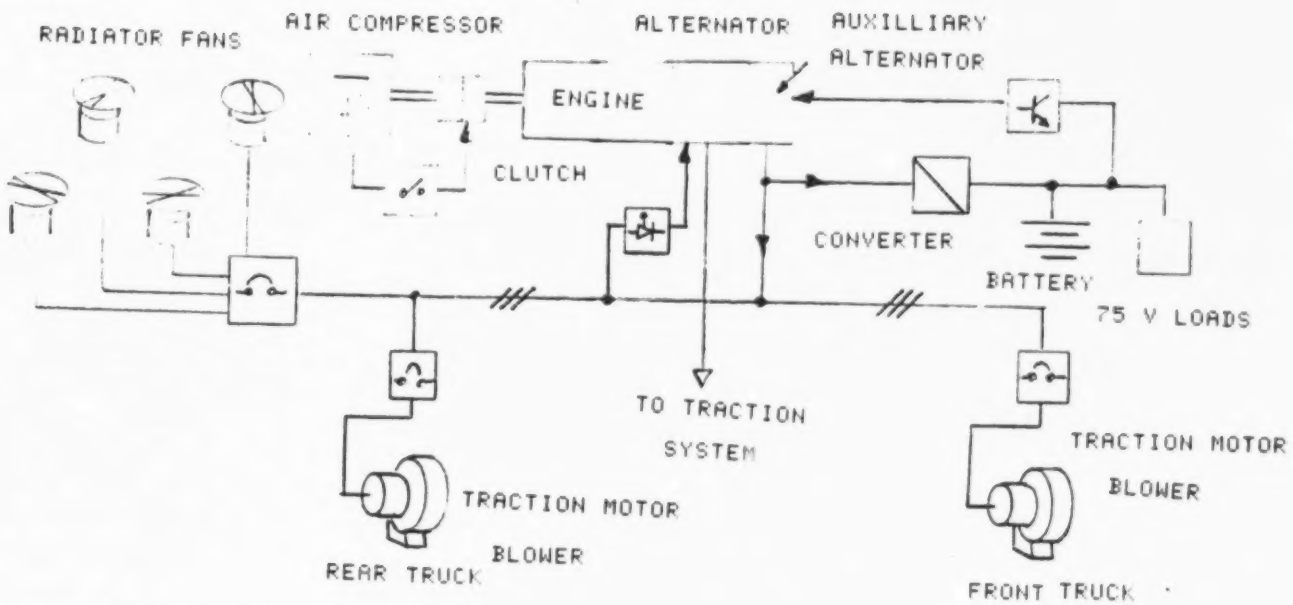
The auxiliary loads will be considerably reduced for a switcher locomotive equipped with this drive concept as can be seen in Figure 13 bottom.

4.7 Trucks

There are a variety of trucks that have proven suitable over the years for switcher service which is normally limited to relatively slow yard movements and maximum speeds not exceeding 50 km/h. Trucks designed specifically for switcher service are relatively simple in that many of them do not have any secondary suspension or lateral control devices and are usually equipped with friction-type center plates. Light-weight low-powered switchers, especially those found in Europe and in some North American industrial applications, are even built with the axles fixed in the underframe when only two or three axles are required to support the weight of the locomotive. The type and method of power transmission from the prime mover to the wheels and the service for which a locomotive is designed are therefore the dominant factors in truck selection.



MECHANICAL DRIVES



ELECTRICAL DRIVES

FIGURE 14

AUXILIARY POWER CONCEPTS

As was pointed out in section 4.2,the standard axle-hung traction motor configuration is well suited for North American applications. Four powered axles will be required and consideration must be given to high speed (up to 110 km/h) running in mainline operation. It will be necessary to use a two-axle truck configuration incorporating lateral control and secondary suspension in order to perform properly at high speeds. The locomotive underframe design developed for this switcher locomotive, however, is flexible enough to accept a variety of two-axle truck configurations. For economic reasons, it may prove reasonable to apply one of the simpler switcher type trucks if it is determined in advance that a particular locomotive will be dedicated to slow-speed switcher service.

Weight transfer between axles of a truck caused by reaction to traction motor torque must also be given consideration especially at higher tractive effort levels, since it affects the pulling power of the locomotive and is ultimately a negative factor in establishing the overall efficiency of a locomotive design. Trucks which are secured under the locomotive with friction type load bearing center plates have proven ineffective from the standpoint of limiting weight transfer to an acceptable amount.

Another consideration, especially in switching service and branch line service with severe curving conditions, is excessive wheel flange wear which ultimately results also in track damage. A design encompassing sufficient freedom of movement for each axle exists wherein the axle "steers" into a curved section of track reducing the angle of attack and resulting in a substantial reduction in both wheel and rail wear. This feature tends to complicate the detail design for a steerable axle truck but the benefits that can be realized by specific users with a high proportion of curving track could easily exceed the increased first cost of a truck so equipped.

There are other determining factors in truck selection such as the choice of wheel diameter, the type of brake rigging, etc. but the dynamic performance of the truck in producing a safe, comfortable ride under conditions of optimum pulling power is generally linked closely with those elements discussed briefly above. Modern truck designs have successfully applied metal/rubber bonded sandwiches as replacements for metal to metal sliding surfaces and also as secondary suspension and lateral control devices where only limited travel is required. This type of component can be easily "tuned" to different loading and/or damping conditions by adjusting the shape and/or the chemistry of the rubber elements.

Computer simulation can now be used effectively in the static and dynamic comparison of truck performance related to pre-programmed track conditions, speed, tractive effort, etc. by inputting numerical values

for each parameter of truck design. Thus the designer can change geometry, spring rates, and other factors until the desired performance represented by the computer output has been achieved.

This allows rapid design iterations for optimization before drawings are produced for prototyping and becomes a powerful tool for the modern truck designer.

Several computer simulations were prepared, taking into account a wide range of track curvatures (up to 30°), normally encountered in switching service. Four different truck configurations were simulated on the various curvatures at two different traction levels in order to determine relative values useful in predicting wheel wear and potential track wear and displacement.

The four truck configurations (all Bo-Bo) are as follows:

ZWT - Zero weight transfer - A design produced by Bombardier to minimize weight transfer between axles in main-line freight service.

AAR - A rigid bolster equalized truck used by several builders for low speed switcher application - was an AAR "standard" configuration but is no longer produced.

Flex - A new simplified truck configuration currently being developed by Bombardier. Has good weight transfer characteristics and can be fitted with metalastic elements of varying designs to suit a variety of service requirements.

Steerable - A two-axle steerable truck, also currently under development by Bombardier. Optimizes the steering axle geometry for all service requirements.

The parameters measured and summarized in Tables 13 through 16 for forces acting at the outer wheel of the leading axle are as follows:

L/V Force Ratio

- Indicates potential for track damage by rolling over the outer rail - steady state value of 0.6 or less is considered a safe level.

Total Lateral Force

- Indicates potential for lateral displacement of rail including rail spreading under severe conditions.

LEADING AXLE - OUTER WHEEL

Curvature Degrees	ZWT	H.T. ZWT	FLEX TRUCK	H.T. FLEX TRUCK	AAR	H.T. AAR	STEERABLE TRUCK	H.T. STEERABLE TRUCK
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.1726	0.2200	0.1524	0.1524	0.2328	0.2661	0.0706	0.2052
4	0.3063	0.3032	0.3171	0.3128	0.3367	0.3362	0.1765	0.3110
6	0.3498	0.3402	0.3947	0.3813	0.3802	0.3799	0.2529	0.3536
8	0.3885	0.3617	0.4398	0.4196	0.4225	0.4096	0.3072	0.3811
10	0.4100	0.3737	0.4762	0.4490	0.4520	0.4306	0.3452	0.3890
12	0.4211	0.3764	0.5067	0.4685	0.4657	0.4361	0.3739	0.3903
14	0.4307	0.3806	0.5209	0.4783	0.4717	0.4373	0.4129	0.3961
16	0.4395	0.3946	0.5287	0.4872	0.4738	0.4383	0.4550	0.4054
18	0.4420	0.4055	0.5345	0.4955	0.4840	0.4446	0.4615	0.4137
20	0.4438	0.4124	0.5399	0.5030	0.4871	0.4563	0.4627	0.4209
22	0.4450	0.4153	0.5456	0.5097	0.4884	0.4664	0.4647	0.4267
24	0.4451	0.4149	0.5611	0.5189	0.4891	0.4743	0.4733	0.4306
26	0.4446	0.4130	0.5748	0.5355	0.4894	0.4791	0.4812	0.4315
28	0.4440	0.4110	0.5869	0.5516	0.4895	0.4806	0.4884	0.4269
30	0.4430	0.4691	0.5977	0.5671	0.4892	0.4789	0.4946	0.4181

H.T. = HIGH TRACTION) Applied torque = 136,500 lb in/axle
Otherwise) Applied torque = 40,950 lb in/axle

TABLE 13

L/V FORCE RATIO

LEADING AXLE - OUTER WHEEL

Curvature Degrees	ZWT	H.T. ZWT	FLEX TRUCK	H.T. FLEX TRUCK	AAR	H.T. AAR	STEERABLE TRUCK	H.T. STEERABLE TRUCK
0	0.	0.	0.	0.	0.	0.	0.	0.
2	5,604	7,119	4,933	4,936	7,378.	7,930	2,295	6,668
4	9,976	9,884	10,514	10,380	10,849	10,239	5,737	10,107
6	11,621	11,304	13,408	12,961	12,496	11,835	8,221.	11,491
8	13,130	12.162	15,260	14,552	14,170	12,969	9,984	12,386
10	14,010	12,650	16,824	15,819	15,379	13,789	11,208	12,644
12	14,467	12,769	18,179	16,685	15,954	14,018	12,153	12,687
14	14,864	12.938	18.824	17,132	16,210	14,074	13,419	12,875
16	15,235	13,512	19,186	17,540	16,297	14,120	14,789	13,177
18	15,347	13,966	19,452	17.916	16,735	14,375	15,001	13,446
20	15,426	14,258	19.703	18,259	16,879	14,845	15,038	13,679
22	15,478	14,385	19.968	18,563	16,938	15,259	15,104	13,868
24	15,489	14,379	20,702	18,987	16,971	15,582	15,382	13,996
26	15,473	14,308	21,361	19.764	16,991	15,786	15,638	14,024
28	15,449	14,230	21,952	20,527	16,998	15,853	15,872	13,876
30	15,422	14,158	22,486	21,279	16,988	15,793	16,074	13,588

TABLE 14

TOTAL LATERAL FORCE - L - (lb)

LEADING AXLE - OUTER WHEEL

Curvature Degrees	ZWT	H.T. ZWT	FLEX TRUCK	H.T. FLEX TRUCK	AAR	H.T. AAR	STEERABLE TRUCK	H.T. STEERABLE TRUCK
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	11.88	22.31	9.60	9.82	24.41	34.70	1.60	20.62
4	74.54	76.07	48.24	48.77	80.49	78.42	7.21	50.90
6	112.66	113.53	93.62	91.89	120.65	116.16	14.04	64.21
8	161.91	149,25	141.43	135.33	167.81	152.08	20.61	85.06
10	223.25	199.34	192.82	179.94	222.07	197.01	26.36	119.02
12	283.09	244.71	246.58	224.88	282.32	243.04	32.29	162.77
14	336.62	289.19	307.63	274.56	340.13	285.86	47.68	194.18
16	376.04	330.76	369.83	326.06	395.57	328.07	84.52	214.85
18	409.12	370.71	433.42	379.75	437.07	368.52	128.81	235.89
20	440.89	406.40	498.84	435.98	469.40	407.93	171.03	257.47
22	470.50	436.48	565.32	495.27	501.15	447.11	209.93	279.82
24	497.32	461.20	620.39	555.17	532.17	484.10	230.97	303.28
26	522.75	482.85	673.99	610.93	562.02	516.96	252.42	328.41
28	547.50	503.67	725.76	668.53	590.02	544.10	274.36	356.11
30	576.21	524.18	775.95	728.07	615.74	565.30	297.05	384.71

TABLE 15

ANGLE OF ATTACK * LATERAL FORCE (lb)

LEADING AXLE - OUTER WHEEL

Curvature Degrees	ZWT	H.T. ZWT	FLEX TRUCK	H.T. FLEX TRUCK	AAR	H.T. AAR	STEERABLE TRUCK	H.T. STEERABLE TRUCK
0	.029	.108	.029	.107	.074	.175	.029	.107
2	.217	.317	.198	.206	.338	.443	.070	.313
4	.772	.771	.499	.474	.769	.768	.178	.507
6	1.015	1.007	.772	.720	1.014	.984	.304	.578
8	1.294	1.232	1.025	.944	1.252	1.177	.439	.722
10	1.660	1.583	1.264	1.154	1.525	1.435	.586	.972
12	2,027	1.928	1.491	1.366	1.855	1.743	.748	1.304
14	2.342	2.251	1.772	1.619	2.187	2.046	.932	1.530
16	2.559	2.467	2.067	1.876	2.520	2.345	1.130	1.658
18	2.770	2.677	2.369	2.138	2.718	2.590	1.336	1.789
20	2.975	2.877	2.675	2.409	2.902	2.778	1.565	1.92
22	3.172	3.065	2.978	2.693	3.094	2.965	1.796	2.064
24	3.358	3.242	3.158	2.954	3.284	3.145	1.940	2.219
26	3.541	3.414	3.331	3.125	3.471	3.318	2.084	2.397
28	3.722	3.583	3.497	3.295	3.649	3.480	2,228	2.623
30	3.929	3.750	3.657	3.465	3.818	3.631	2.376	2.888

TABLE 16

TREAD - CREEP PERCENTAGE

Angle of Attack

- Indicates potential for wheel flange wear and the possibility of derailment from a wheel climbing over the rail head.

Tread Creep

- Indicates potential for accelerated wheel tread wear.

None of the truck configurations compared under the above stated simulated conditions were found to be unsafe or unstable. However, it is obvious that the steerable truck would be superior to the others from the standpoint of wheel and track wear or damage. The reduced values of the measured parameters also indicates that the steerable truck has the potential for improved traction performance when negotiating track conditions normally encountered in switching service.

It must now be considered that both the steerable axle and the flex truck designs have not yet been produced as full-scale prototypes whereas the ZWT has seen considerable service and the AAR truck (although no longer in production) is often available for retrofitting. The steerable-axle and flex-truck designs will, no doubt, achieve future production status but until other factors, such as first cost and maintainability are known, it would be unreasonable to recommend either for exclusive switcher application.

Therefore, the locomotive conceptual design will remain flexible to the extent that any one of the several truck configurations can be fitted to it, depending on the cost and performance factors, which will make the locomotive more acceptable to specific customers and under specific operating conditions.

5. PRELIMINARY LOCOMOTIVE DESIGN

Conceptual drawings were prepared to illustrate several possible configurations resulting from this study. Figures 7 through 10 represent typical locomotive outline drawings, giving only a few overall dimensions, while showing the general arrangement for all major pieces of equipment.

A logical series of drawings have been prepared so that the switcher and transfer configurations could be shown with both the in-line 6 cylinder and the V-8 prime mover installed. Three of the drawings portray the steerable-truck configuration while the fourth was prepared with the zero-weight-transfer truck.

All four locomotives have the same overall dimensions and except for the above-mentioned trucks, are identical below the main floor frame. A significant variation in external appearance above deck can be readily observed in the cab arrangements due to the difference between switcher and transfer applications with corresponding changes in seating arrangements, window placement, location of controls, etc.

Another very visible variation is that of the engine room equipment differences between those required for the lower-powered 6 cylinder in-line engine and the V-8 configuration. Both systems are designed, however, to fit within the same low profile hood outline, although different doors and air inlet openings change the external appearance of the hoods.

The transmission system shown is 3-phase A.C. traction for all four locomotives together with the Concept 2 auxiliary powr system based on the use of an auxiliary alternator and electric motor drives for fans and blowers. These systems require a large space allocation above deck. The other systems identified in this study would be able to fit within the same confines, should they be chosen as preferrable alternates.

The various configurations are briefly described as follows:

8 Cylinder Transfer Locomotive (Ref. Figure 7)

This locomotive configuration could easily be the most popular of the four designs, since it combines high power capability with a spacious cab arrangement identified as desireable by the Class I railroads.

6 Cylinder Transfer Locomotive (Ref. Figure 8)

This configuration is the same as for the 8 cylinder version but

addresses the low power requirement that would be more suitable for short-line railroads and those providing bridge service between Class I railroads.

8 Cylinder Switching Locomotive (Ref. Figure 9)

The only difference between this configuration and the transfer version above is the substition of a switcher-type cab designed primarily for better visibility under yard switching conditions.

6 Cylinder Switching Locomotive (Ref. Figure 10)

For low power applications the 6 cylinder engine will be used in place of the V-8. This will probably prove to be the more desirable switching version when the higher power of the V-8 is not required for a given customer's operational requirements.

The four locomotive designs, which have been identified here, have a large degree of modular systems design and standardization of components. However, from a manufacturing viewpoint, significant additional economies could be realized, if only one locomotive configuration were to be universally adopted. This may ultimately prove to be the most desireable approach although an attempt was made to provide in these four configurations a flexibility which some customers feel is essential.

6. ECONOMIC ANALYSIS

A preliminary economic analysis has been prepared to assist in evaluating the economic benefit to the railways of purchasing a new "high technology" switcher rather than maintaining or rebuilding existing low horsepower units for this purpose. The study supposes that the railway has three choices:

1. Maintain an existing unit for 10 more years, and then replace it with a rebuilt unit.

2. Rebuild an existing unit, making maximum use of state-of-the-art conventional technology for engine and control system.

3. Purchase a high technology locomotive as defined by this study.

The analysis is based upon establishing the present value of projected savings due to improved performance.

Assumptions:

Real cost of money (Interest - Inflation) = 5%
Real rate of increase of fuel costs = 0%

Baseline locomotive parameters and estimation of improvements:

Locomotive	Baseline	Rebuild	High Technology
Cost	Deferred	540,000	900,000
Life (yrs)	10	20+	20+
Adhesion	16%	20%	26%
Mileage/yr	75,000	75,000	75,000
Fuel consumption	115,000		
(gal/yr improvement)	0%	8%	13%
Availability	80%	85%	90%
Maintenance	75,000		
Improvement	0%	10%	25%

Present value taken to 10 years only.

Locomotive	Baseline	Rebuild	High Technology
Initial Cost (1)	348,000	540,000	900,000
Value of Adh. (2)	-	67,500	281,250
PV annual fuel (3)	-	80,000	130,000
(savings $1.50 gal)			
PV Increased Avail (4)		33,750	112,500
PV Maintenance Sav.(5)		43,275	108,200
(PV of projected Savings	348,000	315,475	268,050

The following assumptions pertain to the present value calculation:

(1) PV of delay of 540,000. expenditure for 10 years =
$\frac{540,000}{(1.05)9} = 348,000$

(2) Increased adhesion in typical service will be 50% effective in reducing fleet size, assuming power is not the limiting factor.

i.e. $\frac{\text{rebuild}}{\text{baseline}} = \frac{0.20}{0.16} = 1.25$

25%/2 = 12½%

$\frac{\text{new}}{\text{baseline}} = \frac{0.26}{0.16} = 1.625$

62.5%/2 = 31.25%

i.e The effective purchase price of the rebuild and new locomotives can be reduced by 12½% and 31.25% in comparison with the baseline, as fewer locomotives will be required in this proportion to do the same work.

(3) PV of annual operation cost savings at 5% real cost of money (based on saving of $1)

Year	PV
1	1.000
2	0.952
3	0.907
4	0.864
5	0.823
6	0.784
7	0.746
8	0.711
9	0.677
10	0.645
	8.11

(4) Same assumptions as 2) except 100% of increased availability can be used to reduce the fleet size requirement.

i.e. rebuild = $\frac{85}{80} = 1.0625 = 6.25\%$

new = $\frac{90}{80} = 1.125 = 12.5\%$

(5) Annual savings X PV factor from 3).

In conclusion, any economic evaluation of this type must by definition be arbitrary, and the results will vary with the assumptions made. This analysis does show, however, that a new high technology switcher/transfer locomotive should be an attractive and economically viable alternative to a railway deciding upon it's next generation of power in this category.

GLOSSARY OF TERMS

1.	Axle Loading:	Total allowable weight per axle.
2.	Bolster:	Truck structural member supporting the chassis.
3.	Cab:	Drivers operating area where controls are located.
4.	Class I:	Railway with minimum Annual Operating Revenues of at least US$ 50M.
5.	Class II:	Railway with Annual Operating Revenues of between US$ 10M and US$ 50M.
6.	Class III:	Railway with Annual Operating Revenues of less than US$ 10M.
7.	Expansion Tank:	Tank to allow for expansion of engine water.
8.	Pollution Tank:	Tank provided to collect run-offs from the engine & compressor.
9.	Response Time:	Time required for response when applying or removing a load.
10.	Short Hood:	Hood structure located on the locomotive in front of the cab.
11.	Traction Pad:	Transfers the tractive force from the trucks to the underframe.
12.	Tractive Effort:	Force generated by the locomotive on the rail which acts to move the locomotive and train.
13.	Trucks:	Assemblies located beneath the locomotive containing motors, gears and wheelsets, and which act to support and transfer forces to the chassis.
14.	Underfloor:	Assembly which supports the hoods, engine and locomotive equipment, and which, in turn, rests on the trucks.
15.	Unsprung Weight:	Weight resting directly on the axle without benefit of springs.

LIST OF ABREVIATIONS

ROADS	Railroads
AMTRAK	National Passenger Corporation in USA
CONRAIL	Consolidated Rail Corporation
EMD	Electro Motive Division, General Motor Corp.
GMC, GMD	General Motors Canada
GE	General Electric Company
ALCO	American Locomotive Company
MLW	Montreal Locomotive Works
BBD	Bombardier Inc.
VIA	Via Rail Canada
AAR	Association of American Railroads
RR	Railroad
RY	Railway
SLUG	Unit without prime mover containing only traction motors
MATE	Motors to Assist Tractive Effort
FRA	Federal Railroad Administration
SFC	Specific Fuel Consumption
BBC	Brown Boveri Company
AEG	Allgemeine Electrizitaetsgesellschaft
GHP	Gross Horsepower
T.E.	Tractive Effort
I	Electric current
CPR	Canadian Pacific Railways
CNR	Canadian National Railway
EMU	Electric Multiple Unit
PWM	Pulse Width Modulated
ZWT	Zero Weight Transfer
HI-AD	High-Adhesion

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